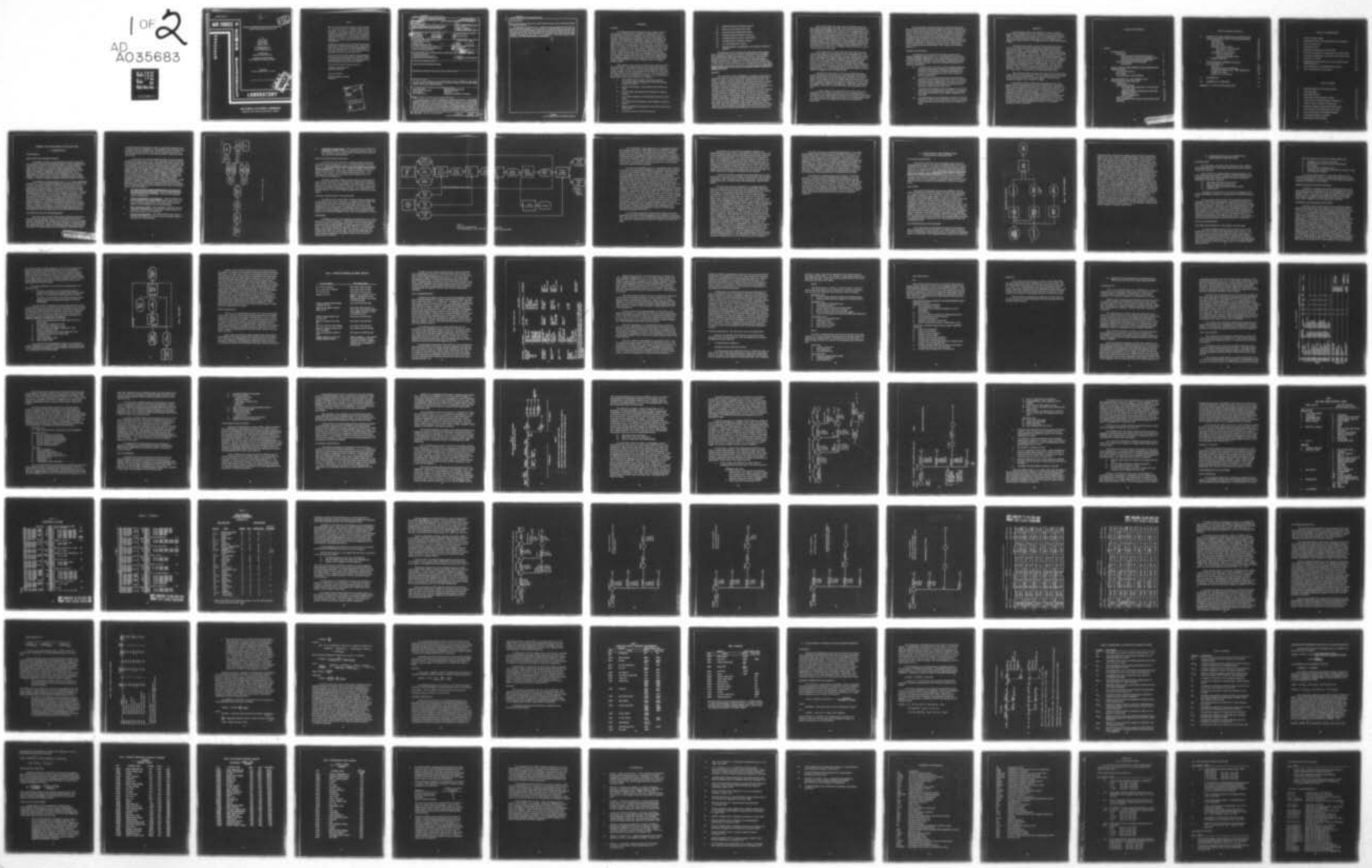
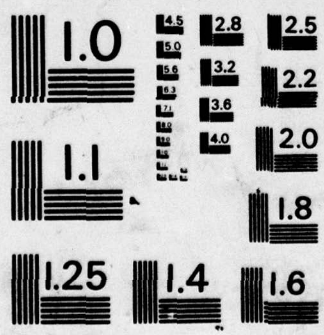
AD-A035 683   DYNAMICS RESEARCH CORP   WILMINGTON MASS   F/G 1/3
DIGITAL AVIONICS INFORMATION SYSTEM (DAIS): CURRENT MAINTENANCE--ETC(U)
OCT 76   H E ENGEL, J M GLASIER, R A DOWD   F33615-75-C-5218

UNCLASSIFIED   AFHRL-TR-76-71   NL

1 OF 2
AD
A035683



3568



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

AFHRL-TR-76-71

AIR FORCE

ADA035683

HUMAN RESOURCES

DIGITAL AVIONICS INFORMATION SYSTEM (DAIS):
CURRENT MAINTENANCE TASK ANALYSIS

By

Herbert E. Engel
John M. Glasier
Richard A. Dowd
Marjorie A. Bristol

Dynamics Research Corporation
60 Concord Street
Wilmington, Massachusetts 01887

H. Anthony Baran
Duncan L. Dieterly, Major USAF

ADVANCED SYSTEMS DIVISION
Wright-Patterson Air Force Base, Ohio 45433

October 1976
Final Report for period May 1975 – June 1976

LABORATORY

AIR FORCE SYSTEMS COMMAND
BROOKS AIR FORCE BASE, TEXAS 78235

NOTICE

When US Government drawings, specifications, or other data are used for any purpose other than a definitely related Government procurement operation, the Government thereby incurs no responsibility nor any obligation whatsoever, and the fact that the Government may have formulated, furnished, or in any way supplied the said drawings, specifications, or other data is not to be regarded by implication or otherwise, as in any manner licensing the holder or any other person or corporation, or conveying any rights or permission to manufacture, use, or sell any patented invention that may in any way be related thereto.

This final report was submitted by Dynamics Research Corporation, 60 Concord Street, Wilmington, Massachusetts 01887, under contract F33615-75-C-5218, project 2051, with Advanced Systems Division, Air Force Human Resources Laboratory (AFSC), Wright-Patterson Air Force Base, Ohio 45433. Mr. H. Anthony Baran, Personnel and Training Requirements Branch, was the contract monitor.

This report has been reviewed and cleared for open publication and/or public release by the appropriate Office of Information (OI) in accordance with AFR 190-17 and DoDD 5230.9. There is no objection to unlimited distribution of this report to the public at large, or by DDC to the National Technical Information Service (NTIS).

This technical report has been reviewed and is approved.

GORDON A. ECKSTRAND, Director
Advanced Systems Division

Approved for publication.

DAN D. FULGHAM, Colonel, USAF
Commander

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: AFHRL-TR-76-71	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle): DIGITAL AVIONICS INFORMATION SYSTEM (DAIS): CURRENT MAINTENANCE TASK ANALYSIS		5. TYPE OF REPORT & PERIOD COVERED: Final rept. May 1975 – June 1976
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s): Herbert E. Engel, John M. Glasier, Richard A. Dowd, Marjorie A. Bristol, H. Anthony Baran, Duncan L. Dieterly		8. CONTRACT OR GRANT NUMBER(s): F33615-75-C-5218
9. PERFORMING ORGANIZATION NAME AND ADDRESS: Dynamics Research Corporation, 60 Concord Street, Wilmington, Massachusetts 01887		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: 63243F, 20510001
11. CONTROLLING OFFICE NAME AND ADDRESS: HQ Air Force Human Resources Laboratory (AFSC), Brooks Air Force Base, Texas 78235		12. REPORT DATE: October 1976
		13. NUMBER OF PAGES: 96
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office): Advanced Systems Division, Air Force Human Resources Laboratory, Wright-Patterson Air Force Base, Ohio 45433		15. SECURITY CLASS. (of this report): Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

18 19 6 10 9 15 16 17 00 11 12 96p.

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

The study was jointly sponsored by Air Force Human Resources Laboratory (AFHRL), Air Force Avionics Laboratory, and Air Force Logistics Command. It was performed and funded as part of the Digital Avionics Information System Advanced Development Program.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

avionics maintainability
avionics maintenance task analysis
avionics reliability
close air support avionics
Digital Avionics Information System
integrated avionics system
life cycle cost
reliability and maintainability factor projections

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The equipment used as the basis for performing this maintenance task analysis is a DAIS-configured conceptual design configuration described in *Mid-1980s Digital Avionics Information System Conceptual Design Configuration,* AFHRL-TR-76-59. It is an avionics design configuration suitable for a close air support (CAS) mission that is based on currently available military inventory but reconfigured in accordance with DAIS concept of sensors communicating with a central processor and integrated controls and displays through a multiplex bus. This report describes the methodology used in obtaining reliability and maintainability (R&M) data; its display in a standardized schematic format called a Maintenance Task Network; the partitioning of the historical R&M factors in accord with the hardware partitioning; and the use of figures of merit, derived from the partitioned R&M data, to → OVER

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

Unclassified 388 902

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

Code

Item 20 (Continued):

rank the subsystems in terms of their impact on mission effectiveness, manpower resources utilization, and operation and maintenance (O&M) costs.

The maintenance task analysis will serve as a baseline for a second maintenance task analysis based on a mid-1980s DAIS design configuration. It will provide inputs for an R&M model which will, in conjunction with standard cost factors, permit the computation of O&M costs. It will provide the equipment-related portion of the data needed for the operation of the DAIS training model which will derive the best methods to train the required maintenance manpower. The numerical values derived from the maintenance task analysis appear as the current maintenance task analysis data bank. This has been accomplished in a format totally compatible with the requirements of the AFHRL Maintenance Manpower Modeling System.

SUMMARY

Problem

The Digital Avionics Information System (DAIS) seeks to demonstrate a solution to the problem of proliferation and non-standardization of aircraft avionics. Since the DAIS concept of avionics integration has the potential to produce substantial cost benefits, it is importnat to assess the impact of operational implementation of the DAIS on the USAF operational and logistics support system in terms of life cycle cost (LCC). To this end, a DAIS LCC study was undertaken. The fundamental objective of this study is to provide the Air Force with an enhanced in-house capability to incorporate LCC considerations, during all stages of the system acquisition process, into the following tradeoff areas: system design, system operation and maintenance, and planning for manpower utilization and training. The specific application of the resultant capability will be to evaluate the LCC of alternative design configurations for a DAIS-configured close air support (CAS) aircraft.

This report is the second in a series which reports the overall study efforts. The output products of the study will consist of technical reports, data banks, and computer programs which will, in their totality, provide the elements for the DAIS Life Cycle Cost Modeling System, the methodology for its use, and a description of the manner in which the results were obtained. A list of these products in the order of their delivery is as follows:

1. Mid-1980s Digital Avionics Information System Conceptual Design Configuration (Technical Report), AFHRL-TR-76-59
2. Current Maintenance Task Analysis Data Bank (Data Bank)
3. Current DAIS Maintenance Task Analysis (Technical Report)
4. Mid-1980s Maintenance Task Analysis Data Bank (Data Bank)
5. Mid-1980s DAIS Maintenance Task Analysis (Technical Report
6. Support Equipment Maintenance Task Analysis Data Bank (Data Bank)
7. Reliability Model (Computer Program)

8. Reliability Model (Technical Report)
9. Historical Data Bank (Data Bank)
10. Theoretical Data Bank (Data Bank)
11. Training Model (Computer Program)
12. Training Model Data Bank (Data Bank)
13. Training Model (Technical Report)
14. Cost Data Bank (Data Bank)
15. Modeling System Compatibility and Potential (Technical Report)

The objective of the current DAIS maintenance task analysis (MTA) reported herein was to develop a data bank of the reliability and maintainability (R&M) parameters inherent in a current DAIS-configured CAS avionics suite. The subject avionics conceptual design configuration is composed of presently available subsystems overlaid with the DAIS architecture. Its development and specification are described in the first of the series of technical reports, Mid-1980s Digital Avionics Information System Conceptual Design Configuration, AFHRL-TR-76-59.

Approach

The importance of the availability and validity of input data to the performance of a good maintenance task analysis cannot be overstated. To ensure that the needs of the analysis would be met, the required outputs were first identified. The inputs necessary to supply the data required to generate those outputs were then determined. Potential sources were identified and the best R&M data available was collected, recorded, and validated when possible. R&M data of existing avionics subsystems that were identical to or at least similar to those chosen as a baseline non-DAIS current CAS avionics suite provided the most valuable inputs. Starting with the subsystems identified as those to be partitioned for the current DAIS conceptual design configuration, a data bank was constructed using operational R&M data for those subsystems. This non-DAIS avionics engineering data bank served as a baseline for the construction of the current DAIS MTA data bank described in this report. Comparisons between these data banks provides an immediate overview of the impact of the DAIS concept on the R&M characteristics of a current CAS aircraft.

The current DAIS MTA data bank was developed from the aforementioned non-DAIS data bank. This entailed the projection of the configuration changes, which resulted from the application of the DAIS concept, onto the R&M parameters for the selected subsystems in accordance with the equipment partitioning identified in the conceptual design. Partitioning involves the division of the subsystem hardware by functional purpose into sensor, processor, and control/display sections. The combination of these partitioned sensors with the DAIS multiplex bus, processors, control/display, and software constitutes the current DAIS conceptual design configuration. The R&M parameter values of this configuration provide the data for the current DAIS MTA data bank.

The content of the current DAIS MTA data bank was determined on the basis of an examination of its foreseeable uses. Two sets of requirements were identified. One set required an interface with the manpower and support equipment (SE) requirements of the LCC model, the second with the training analysis portion of the model. In view of this clear division of requirements a design decision was made to have the current DAIS MTA and the resulting current DAIS MTA data bank deal with the first of these two sets of requirements, i.e., the equipment R&M parameter values and their impact on manpower and SE requirements.

The R&M characteristics of the current DAIS conceptual design configuration were examined. Data elements were selected which could be used to define and quantify subsystem parameters useful in exercising the various models within the overall DAIS LCC study. Included among these parameters or figures of merit (FOM) are maintenance manhours per flight hour (MMH/FH), operational availability, mean time to repair (MTTR), and maintenance index (MI).

A major output of the overall DAIS LCC study will be the integration of its various products into a LCC modeling system. A description of the requirements established for the interfaces between the MTA and the other components of this LCC modeling system plus the requirements for the input data collected are provided in Section III.

The calculation of the R&M values for each task associated with maintenance of the partitioned equipment and the construction of the data bank represent the major portion of the effort covered by this report. Section IV describes how this was accomplished. Analytical results, in the form of subsystem rankings in terms of operational availability and maintenance manhours/1000 flight hours, provide visibility to those portions of the current DAIS conceptual design configuration which can be expected to be the drivers of operational readiness and operations and maintenance (O&M) costs, respectively. These rankings and an interpretation of the results are included in Section V.

Results and Conclusions

An analysis was conducted to determine manpower and support equipment requirements for a representative current DAIS conceptual design configuration. The results were incorporated into a current DAIS MTA data bank. The information included in this data bank and the format in which it has been implemented provide the following capabilities:

a) It can be used to drive the Air Force Human Resources Laboratory Maintenance Manpower Modeling System (MMMS) in determining the detailed utilization of resources in maintaining the current DAIS conceptual design configuration.

b) It can serve to provide the previously described R&M figures of merit for each subsystem in the current DAIS conceptual design configuration. This allows an assessment of the major system problem areas in terms of operational readiness and O&M costs.

c) It serves as the baseline for the development of the mid-1980s DAIS conceptual design configuration maintenance task analysis data bank and the support equipment (SE) data bank.

d) It provides inputs to the maintenance manpower training analysis in terms of task requirements and the reliability model being developed as part of the overall DAIS LCC study.

PREFACE

This technical report is the second of a series of reports under contract F33615-75-C-5218, "DAIS Life Cycle Costing Study" which, in combination with present Air Force capabilities, will provide the means to assess the life cycle cost (LCC) impact of the operational implementation of the Digital Avionics Information System (DAIS).

The study was directed by the Advanced Systems Division, Air Force Human Resources Laboratory, Wright-Patterson Air Force Base, Ohio. It was performed under Air Force Avionics Laboratory Program Element 63243F, "Digital Avionics Information System", Project 2051. Project 2051, "Impact of DAIS on Life Cycle Costs", is jointly sponsored by the Air Force Human Resources Laboratory, Air Force Avionics Laboratory, and Air Force Logistics Command. Contract funds were provided by the Air Force Avionics Laboratory. The DAIS Program Manager is Maj. John G. Weber. The DAIS Chief Engineer is Mr. Frank Scarpino. The Air Force Human Resources Laboratory Project Scientist is Maj. Duncan L. Dieterly. The Air Force Logistics Command Project Officer is Mr. Ron Greene. The latter two are DAIS Deputy Directors.

This research effort is documented under Work Unit 20510001, "DAIS Life Cycle Costing Study". Mr. H. Anthony Baran is the Work Unit Scientist and Air Force Contract Monitor. The contractor Program Manager is Mr. Herbert E. Engel.

The authors wish to extend their appreciation to the many people within the Government and private industry who contributed their time and expertise throughout the course of this research. Too numerous to mention by name, it must be sufficient to note that considerable assistance was rendered by: the DAIS engineering staff; personnel at the San Antonio and Oklahoma City Air Logistics Centers; Air Force Logistics Command Headquarters; Aeronautical Systems Division; various organizations within the U.S. Navy including the Naval Weapons Engineering Support Activity, the Naval Air Systems Command Headquarters, and the A-7E Program Manager's Office (PMA-235).

TABLE OF CONTENTS

Table of Contents (continued)

LIST OF ILLUSTRATIONS

LIST OF TABLES

CURRENT DAIS MAINTENANCE TASK ANALYSIS

I. INTRODUCTION

BACKGROUND

DAIS Advanced Development Program

The Digital Avionics Information System (DAIS) concept has the potential of bringing substantial benefits to system reliability and cost because it gives: (1) an enhanced ability to modify software rather than hardware to meet new mission requirements, (2) the potential for improved reliability through the planned use of redundancy at subsystem, equipment, and component levels, (3) an opportunity for adding new sensors and capabilities to the system without rewiring the aircraft, and (4) an effective means for using modular or common equipment designs on different types of aircraft.

To capitalize on this potential, the U. S. Air Force established in July 1973, a DAIS advanced development program (DAIS ADP). The Air Force Avionics Laboratory (AFAL) is the lead agency and is coordinating the efforts of AFAL, the Aeronautical Systems Division, the Aerospace Medical Research Laboratory, the Air Force Flight Dynamics Laboratory, the Air Force Armament Laboratory, the Rome Air Development Center, the Air Force Logistics Command, and the Air Force Human Resources Laboratory. Their objectives are to demonstrate the DAIS concept on a functional basis and to develop: (1) an in-house cadre of skilled personnel who can perform preliminary design and. (2) prepare specifications,standards and techniques for the four common or core elements of all avionic systems, namely, multiplex, processors, control and displays, and software. To advance the time and degree of DAIS concept implementation, a DAIS integrated test bed and software test stand have been planned.

The DAIS Life Cycle Cost Modeling System

Over the years, several facts related to systems acquisition have become increasingly clear: (1) the increasing complexity of mission requirements has resulted in the need for an ever-increasing use of new technology, (2) the resources necessary to implement this new technology and to support the resulting systems are dramatically increasing, (3) budget constraints and manpower limitations dictate

a critical need for obtaining the required operational capability with minimum resource expenditures, (4) acquisition costs represent only a portion of the total system LCC, and (5) decisions made early in the conceptual phase have the greatest potential to reduce life cycle cost (LCC).

In the past, LCC has been used primarily to track or predict operation and maintenance costs. Cost reductions have been effected by selecting logistic actions which minimize costs once a system has been acquired. In order to exercise maximum effect, however, LCC considerations must be introduced in the acquisition process early enough to impact the design of the hardware, the software, and their support system. The DAIS LCC Modeling System is designed to provide the USAF with an enhanced in-house capability to incorporate LCC considerations into avionics design, planning of training, and operation and maintenance at all stages of the weapon system acquisition process including conceptual design. In particular, it will provide a capability to evaluate the LCC of alternative design configurations for a mid-1980s DAIS-configured CAS aircraft. Design of the LCC Modeling System has been structured in terms of five major tasks as shown in Figure 1:

- Develop Conceptual Design Configurations for Current and Mid-1980s DAIS Avionics Suites. These configurations provide the vehicle for all subsequent efforts in the modeling system development.
- Perform Maintenance Task Analyses. These provide the detailed reliability and maintainability (R&M) data for the conceptual design configurations. They also serve to provide inputs for the development of the training model.
- Select Reliability Model. The reliability model provides the capability to determine R&M parameter values based on design characteristics of the hardware.
- Develop Training Model. The DAIS training model selects methods and media of instruction based on mission effectiveness and cost considerations.

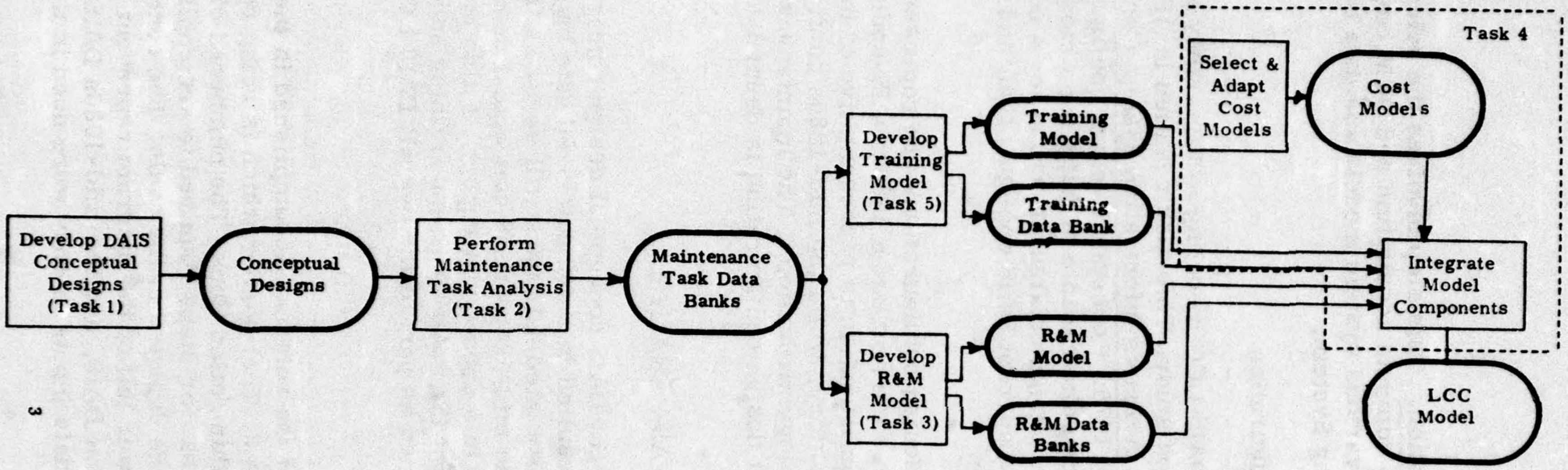


FIGURE 1 DAIS LCC STUDY TASKS

- Integration and Utilization. This step involves the selection of appropriate models to compute acquisition and O&M costs, and the integration of the various system models and data banks to form the LCC Modeling System.

DAIS Conceptual Design Configuration

The first task of the DAIS LCC modeling system study is the conceptual design configuration study. This task resulted in AFHRL-TR-76-59, Mid-1980s Digital Avionics Information System Conceptual Design Configuration, 27 May 1976. Conceptual design configurations were generated for an avionics suite capable of fulfilling a close air support (CAS) mission. These design configurations were: a non-DAIS baseline configuration; a current DAIS configuration; and a mid-1980s DAIS configuration.

The DAIS conceptual design configurations are representative of the avionics suites for both a current and a 1980s DAIS-configured CAS aircraft. The current configuration is representative of the technology in the present day inventory, while the mid-1980s configuration incorporates advanced technology projections. The maintenance task analysis (MTA) of the current design configuration is described in this report.

CURRENT MAINTENANCE TASK ANALYSIS

The MTA for the current DAIS conceptual design configuration as described in this report resulted in a computerized data bank. The current DAIS MTA and its associated data bank will serve as the foundation for the MTA for the mid-1980s DAIS conceptual design configuration to be described in a subsequent report. It also provides inputs to the support equipment (SE) data bank and training and R&M models that are being developed as part of the overall DAIS LCC study.

Methodology

A detailed overview of the subtasks accomplished in the current DAIS MTA is shown in Figure 2. That portion which is being reported in this document is shown within dotted lines. The numbered blocks indicate the four major subtasks or steps required to accomplish the MTA. The primary outputs are depicted in the ovals. The conceptual design inputs shown in the lower left of the diagram represent the baseline non-DAIS, the current DAIS, and the mid-1980s DAIS conceptual design configuration data inputs as they were used in the performance of the MTA.

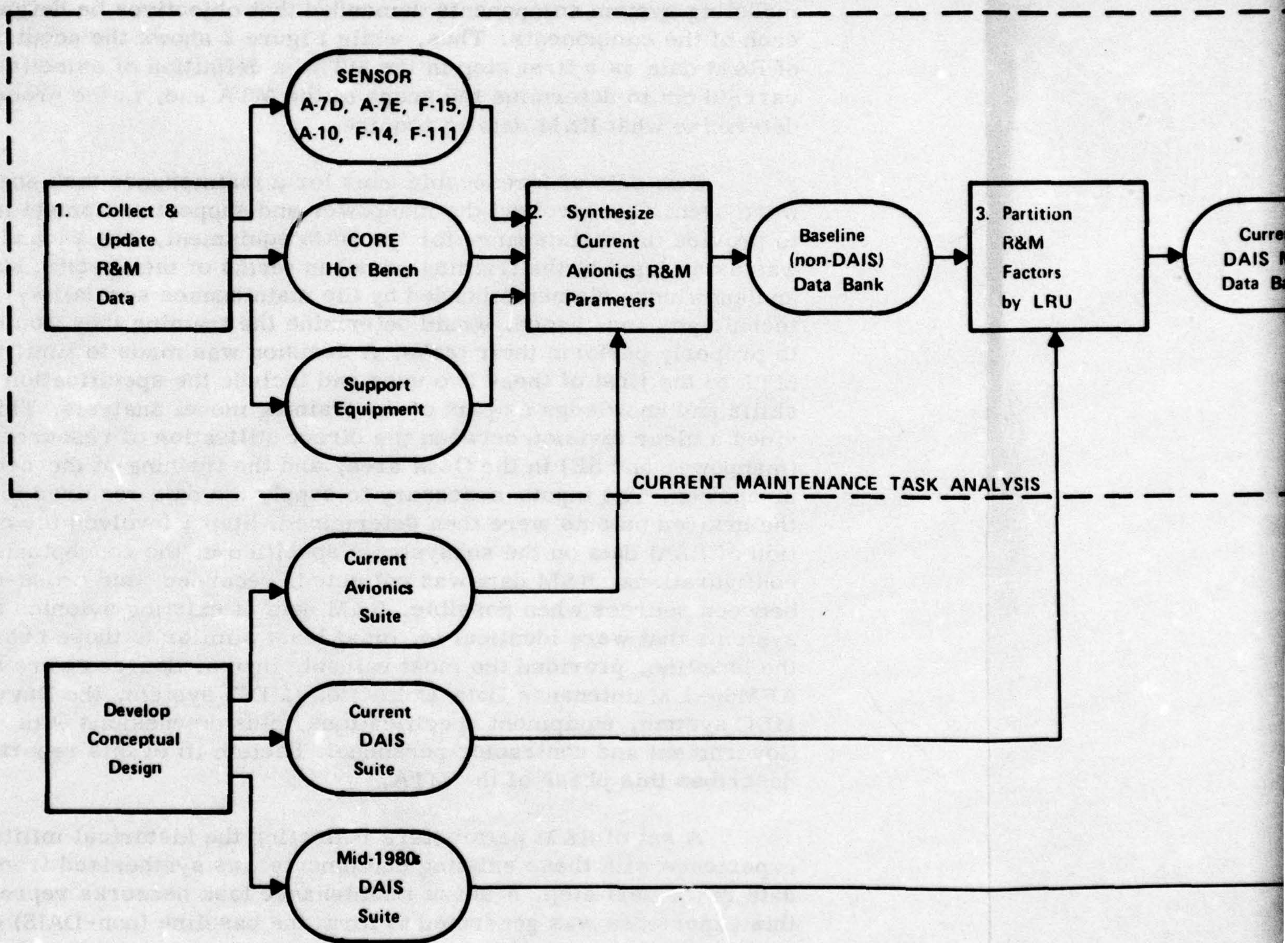
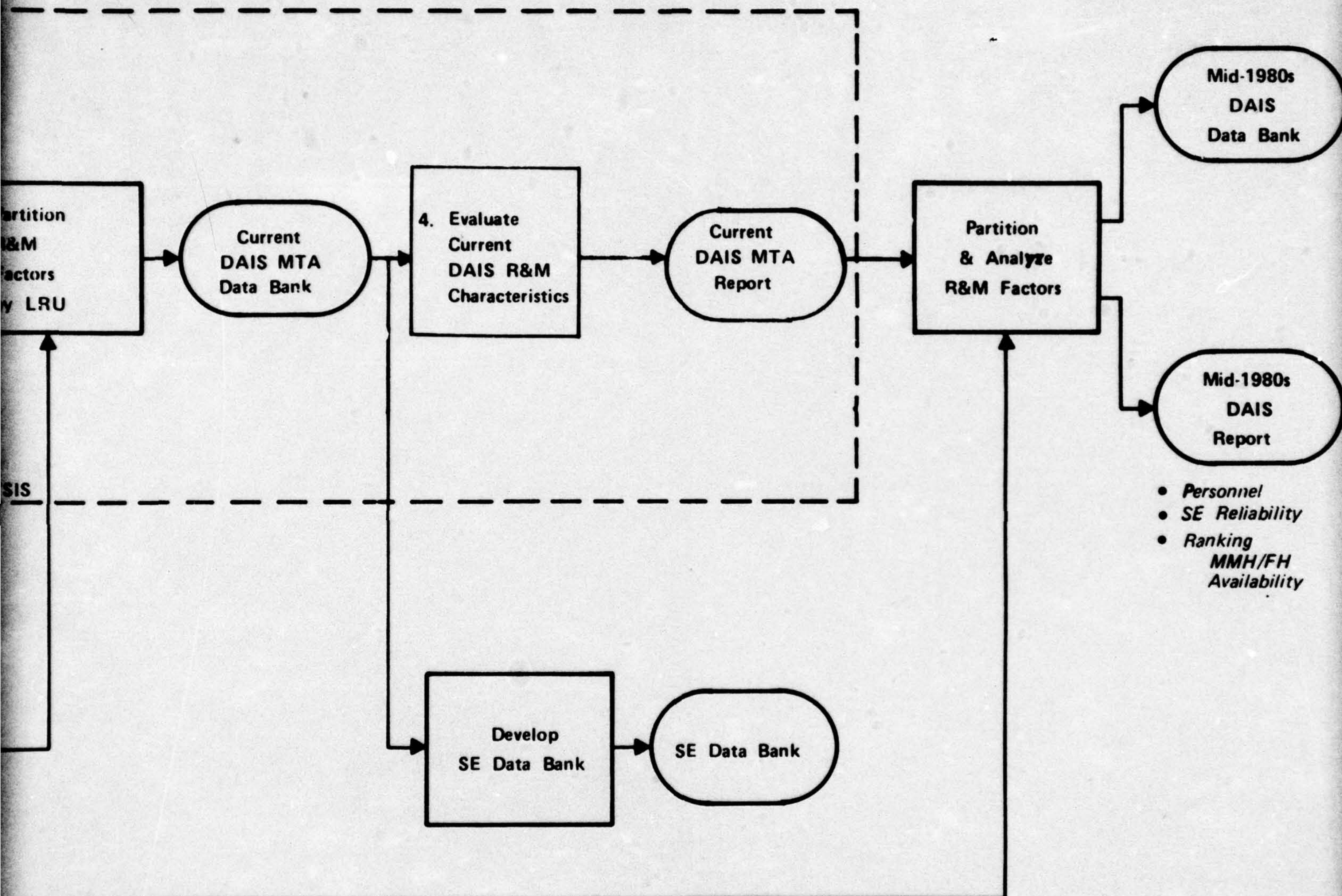


Figure 2
DETAILED OVERVIEW OF
THE MAINTENANCE TASK ANALYSIS



RVIEW OF
NCE TASK ANALYSIS

2

The availability of valid input data is an essential element in performing a good MTA. These inputs must be sufficient to satisfy the needs of the analysis. The broad scope of the LCC Modeling System study and the many interfaces that exist among the various modeling system components demanded that objectives be defined for each of the components. Thus, while Figure 2 shows the acquisition of R&M data as a first step in the MTA, a definition of objectives was carried out to determine the scope of the MTA and, in the process, determine what R&M data to acquire.

Two sets of foreseeable uses for a maintenance task analysis were seen. One involved the manpower and support equipment needed to provide the maintenance for the DAIS equipment. The second use was as an input to the training model in terms of the specific skills and knowledge elements needed by the maintenance specialist/ technicians and, hence, would determine the training they would need to properly perform their tasks. A decision was made to limit the MTA to the first of these two uses and include the specification of skills and knowledge as part of the training model analysis. This provided a clear division between the direct utilization of resources (manpower and SE) in the O&M area, and the training of the necessary manpower. The inputs necessary to supply the data required to obtain the desired outputs were then determined. Step 1 involved the collection of R&M data on the subsystems specified in the conceptual design configurations. R&M data was collected, recorded, and cross-checked between sources when possible. R&M data of existing avionics subsystems that were identical to, or at least similar to those chosen as the baseline, provided the most valuable inputs. Sources were the AFM66-1 Maintenance Data Collection (MDC) system, the Navy's 3M MDC system, equipment specifications, plus discussions with Government and contractor personnel. Section III of this report describes this phase of the MTA.

A set of R&M parameters reflecting the historical military experience with these existing equipments was synthesized from this data in the next step. A set of maintenance task networks representing this experience was generated to form the baseline (non-DAIS) data bank.

Maintenance task networks are graphical displays, in a standardized schematic format, which depict the time-oriented nature of the maintenance tasks and the task R&M characteristics. They provide a visual representation of the relationship of the maintenance tasks to the equipment and to the resources required to perform the tasks. The visualization capability provided affords an easy way to tally the resources utilized in performing the maintenance tasks and facilitates the relating of equipment R&M factors to the "real world". An additional benefit is that the networks are in a form that is compatible with the simulation model which will utilize the data base, the AFHRL Maintenance Manpower Modeling System (MMMS).

A network schematic includes the following R&M data by task: failure rate, mean time to accomplish each task in the repair process, probability of task occurrence, the type of specialist and the number required per task, the skill levels of the technicians, and the SE required.

The third step was the development of an engineering data base from which was constructed the current DAIS MTA data bank. Once the non-DAIS avionics suite had been partitioned into the current DAIS suite, an analogous partitioning of the R&M factors was accomplished. This process analyzed the failure and maintenance histories for each line replaceable unit (LRU) in the total suite. Where failure modes had been altered, replaced, or abolished as the result of the reconfiguration of the hardware, new values were calculated for the resulting reliability (mean sorties between maintenance actions) and maintainability (mean time to repair), task probability of occurrence, manpower, and SE requirements. The method used to perform these calculations is described in detail in Section IV under "Synthesis of R&M Factors". Suffice it to say at this point that the failure frequency, repair times, and consequent manpower and SE were calculated for each subsystem in the current DAIS suite based on its configuration of LRUs. For some of the sensor subsystems the number of LRUs was reduced significantly due to the partitioning. Those LRUs no longer contribute to the failure frequency or the maintenance requirements for those subsystem. However, the functions, if they are to be accomplished in the core element portion of the suite, contribute to the R&M factors for that portion of the total equipment. Thus, the partitioning of the hardware and the reconfiguration of portions of it into the integrated processor and control/displays resulted in a similar partitioning of the R&M factors for the resulting sensors. A new computation of R&M values for the hardware transferred to the core elements was also carried out.

The fourth step was to evaluate the R&M impact on the human and material resource requirements of the DAIS avionics suite. The method chosen was to use the R&M data elements to quantify characteristics of the operation of each subsystem. The parameters or figures of merit chosen include maintenance manhours per flight hour (MMH/FH), non-repair time availability (operational availability) of the subsystems, and maintenance index (MI). These parameters, when compiled in subsystem listings, were analyzed for reasonableness and, when possible, compared with other sources. A result of this check, in addition to confirming the adequacy and accuracy of the data base, is the demonstration of the potential of its usage.

The DAIS LCC modeling system will compute, in the O&M cost area, not only the cost of maintaining the equipment, but also the costs associated with the training of the required maintenance manpower. In order to provide visibility into the system cost drivers it was decided to isolate the resources required by the maintenance system from those required to train the manpower. A discussion of the objectives of the resulting maintenance task analysis, its relationship to those of the DAIS training model, and how both these components will provide total O&M and training costs is contained in Section II.

II. OBJECTIVES OF THE CURRENT DAIS MAINTENANCE TASK ANALYSIS

LCC STUDY OBJECTIVES

The primary objective of the overall life cycle cost (LCC) Modeling System study is to develop a modeling system which can be exercised by the USAF to determine the LCC and manpower requirements for the representative DAIS conceptual design configurations described in AFHRL-76-59, Mid-1980s Digital Avionics Information System Conceptual Design Configuration and to influence design by performing tradeoffs using alternative subsystems and maintenance concepts. The variable elements that bear upon the LCC and the tradeoff analyses are the hardware acquisition costs and those costs associated with the operation and maintenance (O&M) of the equipment.

O&M COSTS

The elements required to operate and maintain a suite of avionics equipment can be broken down into three major categories: i.e., support equipment (SE), manpower (in terms of the numbers and skills required) and spare parts. The effect of equipment reliability and maintainability (R&M) on O&M costs may be seen with reference to Figure 3. Spares requirements may be determined through an analysis of the impact of the equipment R&M on the availability of the subsystems and line replaceable units (LRU) on the flightline. The numbers and types of SE are determined through a requirements analysis which takes into account the equipment design and performance requirements along with its R&M. The numbers and types of maintenance personnel may be determined in an analogous fashion. However, since the manpower skills are provided by means of a training program geared to produce the required skills, the costs of training also play a significant role in determining the O&M cost component of LCC.

THE MAINTENANCE TASK ANALYSIS

The needs of the overall DAIS LCC study are such that two sets of requirements must be served in the O&M area: (1) those of the SE and manpower requirements portion of the DAIS LCC Modeling System, and (2) those of the training analysis portion of the DAIS LCC

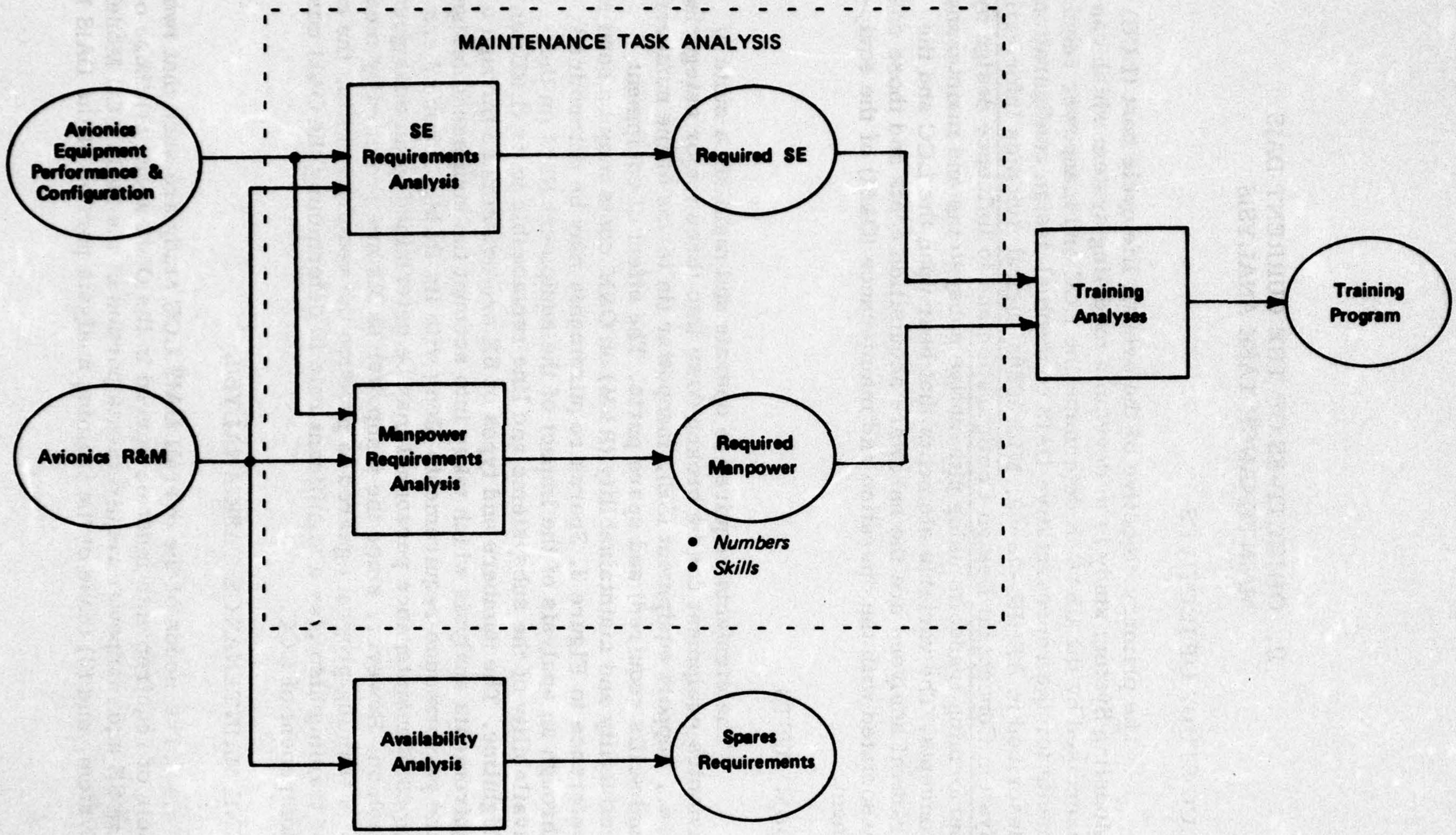


Figure 3 O&M COST ELEMENTS

Modeling System. Because the training analysis (and the subsequent design of the DAIS training model) depend upon a specification of the skill requirements of the maintenance manpower, it was decided to use a two-step approach to the solution of this overall problem. The first step, which is documented in this technical report, presents the results of the portion of the task analysis conducted along the lines of R&M. Specifically available from this effort are the numbers and types of manpower and support equipment required to maintain the individual LRUs and subsystems of the current DAIS conceptual design configuration. These derive from the inherent reliability and maintenance characteristics of these equipments. The second step, which will be documented in a later report, consists of that portion of the task analysis which will define the specific knowledge and skill requirements for each of the types of manpower identified in this report. Specification of these knowledge and skill requirements will form the basis for the training needed by the maintenance personnel. Thus, the first step of the MTA provides results in terms of resources required to support maintenance of this configuration of equipment. The second step provides the input needed to perform the analysis of the required training and the tradeoffs among alternative training methods. It is clear then, that this two-step procedure, while differing in its organization from what many workers in the field consider to be a "classical" maintenance task analysis has the virtue that it provides greater visibility into the isolation among the individual elements that comprise this portion of O&M cost, i.e., the manpower requirements and the manpower training requirements.

III. REQUIREMENTS OF THE CURRENT DAIS MAINTENANCE TASK ANALYSIS

INTRODUCTION

The information provided by the maintenance task analysis (MTA) has several uses. These uses determine the output requirements of the analysis.

Since a total LCC modeling system is being developed, the MTA will provide information to various modules (modeling system components) and study efforts associated with this development. Specifically, these are as follows:

a) mid-1980s DAIS MTA and data bank
b) support equipment (SE) data bank
c) reliability and maintainability (R&M) model
d) training model

In addition, it will serve as a direct source of inputs to the AFHRL Maintenance Manpower Modeling System (MMMS) simulation runs.

First, the input requirements of the subsequent tasks were identified. These were then analyzed to determine which should be provided by the current DAIS MTA. To obtain these outputs, an input data set was identified. Basically, this was comprised of R&M, manpower, and SE data for the subsystems comprising the sensors and core elements of the current DAIS conceptual design configuration. Data sources were identified and the data analyzed to yield the maintenance task networks. These were the task outputs that met the identified requirements of the following study tasks. A description of the interfaces that establishes these requirements is given below.

OUTPUT REQUIREMENTS

Mid-1980s DAIS Maintenance Task Analysis and Data Bank

The current DAIS maintenance task analysis serves as the baseline for the mid-1980s DAIS maintenance task analysis. The latter is greater in scope and includes an analysis of the impact of the central integrated test system (CITS) and associated built-in test/built-in test equipment (BIT/BITE) capability and consolidated SE on the maintenance parameters. The form of the data bank outputs will be similar since both must supply inputs to the AFHRL MMMS simulation runs.

The data required to operate the AFHRL MMMS are:

- frequency of occurrence of the event
- probability that a given task will be performed
- type of task
- time required to complete a task
- manpower and manpower skills needed to perform a task
- test equipment required

A convenient representation of these data elements is the maintenance task network (MTN). A detailed description of the MTN and the methodology for the synthesis of the data elements included in it appears in Section IV of this report.

Support Equipment Maintenance Data Bank

In addition to computing resources consumed and the cost of these resources for maintenance of the avionics equipment, the LCC Modeling System also treats the SE and its maintenance in a similar manner. That is, manpower and manpower skills, and test equipment needed to maintain the SE will be inputs to the LCC model. These will be supplied by the SE maintenance data bank.

Reliability and Maintainability (R&M) Model

The R&M model is used as part of the overall LCC model to project R&M values which act as drivers to the cost portion of the total LCC. In order to allow the most flexible use of the LCC model, i.e., for LCC comparisons between competing inventoried equipments, for comparisons between modified versions of such equipments (such as equipments modified in accord with the DAIS concept), and for the evaluation of equipments in various stages of their development, a set of functional relationships will be developed to relate appropriate system-level characteristics to R&M parameters. The functional relationship concept employed assumes the current DAIS conceptual design configuration as a baseline system. Significant system-level design changes (such as the addition of a central integrated test system, the consolidation of support equipment into automatic and/or semiautomatic test stations) will have a specific and quantifiable impact on the maintenance task parameter values, i.e., the equipment R&M. By determining and evaluating the specific influences these design changes have, modifications to the baseline R&M values may be derived. A block diagram of the implementation

of the R&M model is shown in Figure 4. Two alternate paths are indicated to provide the needed R&M parameters to the logistics support cost (LSC) model. The LSC model is an existing computational tool that was developed by the Air Force to estimate support costs expected to be incurred by adopting a particular system design for a weapon system. The model is used to compare and discriminate among design alternatives where a determination of relative cost differences is the desired result.

The LSC model (Ref. 25) is intended for application in two different areas:

1. To obtain an estimate of the differential logistics support cost between the proposed design configurations of two or more contractors during source selection.

2. To serve as a decision aid when discriminating among design alternatives during prototyping or full-scale development.

The LSC model is comprised of 94 data elements and 10 mathematical equations, each of which describes a portion of the resources required for an operating logistics system. The model operates under the assumption that the best data available will be used to estimate cost and that some information is better than none. The model is exercised by simply summing the following costs described in the <u>Logistics Support Cost Model User's Handbook</u>:

1. Initial and replacement line replaceable unit (LRU) spare costs
2. On-equipment maintenance costs
3. Off-equipment maintenance costs
4. Inventory entry and supply management costs
5. Support equipment costs
6. Personnel training and training equipment costs
7. Management and technical data costs
8. Facilities costs
9. Fuel consumption costs
10. Spare engine costs

It is clear that with modifications related to (a) limiting the model's applicability to avionics and (b) changes made necessary due to new capabilities provided by the DAIS concept, this tool will serve as a useful portion of the R&M model.

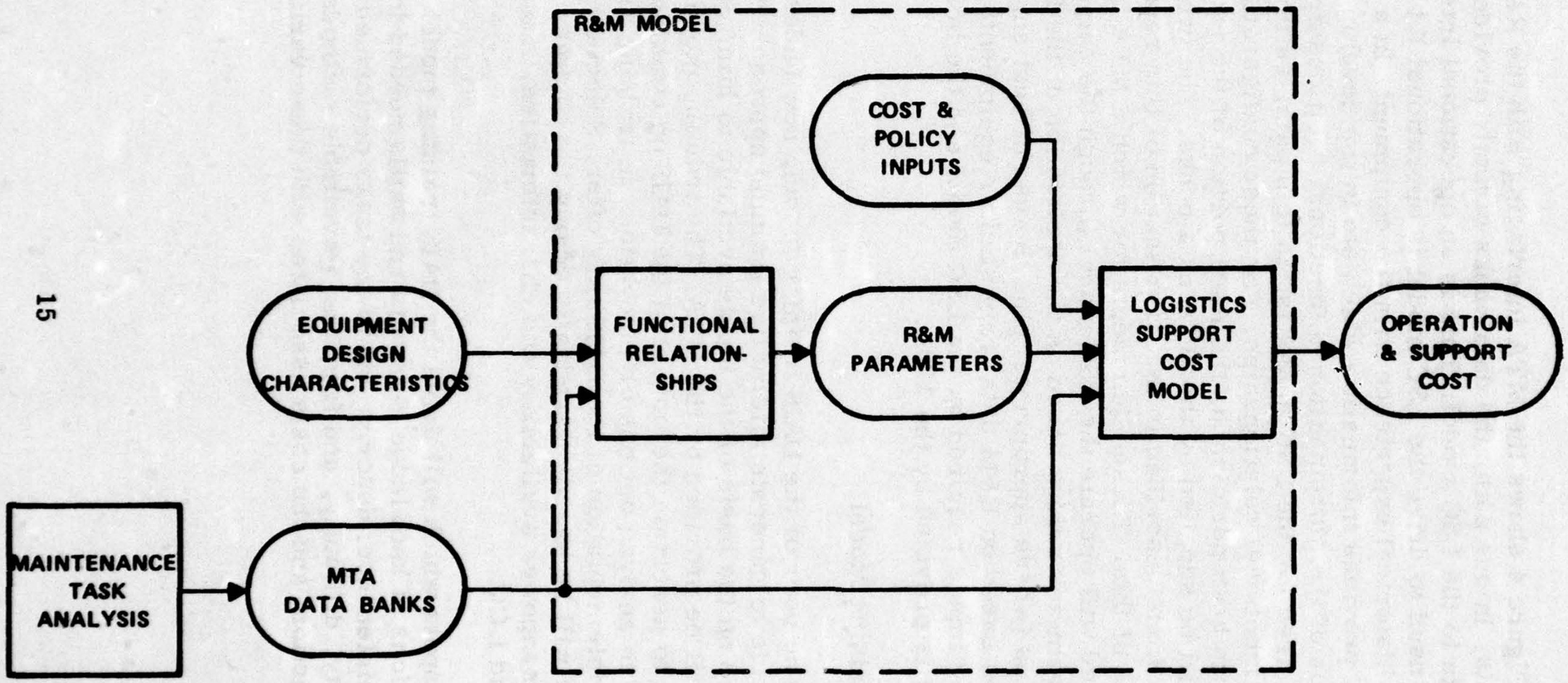


Figure 4 R&M MODEL

Figure 4 shows the MTA interfacing with the R&M model at two points. In one path, the data banks directly provide the necessary R&M data to the LSC model. This is an operational interface in that the data used to drive the LSC model is operational R&M data which reflects historical experience with the equipment. In a second path, the MTA provides information which aid in the development and utilization of the aforementioned functional relationships. The R&M data required for the LSC model is, in this path, estimated by means of these functional relationships. For these configurations for which a MTA has been performed, the R&M portion of the required LSC inputs will be supplied by the MTA data banks. The two DAIS design configurations described in the first section of this report are examples of this. Those equipments for which a MTA has not been performed will operate the LSC model through the computation of R&M parameter values based on the application of the functional relationships (where appropriate) plus the use of best engineering estimates based on R&M data from similar equipments. Table 1 shows the inputs required by the LSC model and the manner in which that data is provided by the MTA.

DAIS Training Model

The user of the DAIS training model, now under construction, will be able to generate alternative training approaches and training programs on the basis of the inputs available to him. Some of these inputs will be provided by the MTA. The training model will provide a means to ascertain the impact of the DAIS on training procedures and also to analyze options or innovations in training procedures which implementation of the DAIS may offer. Selection of the training program will be based on tradeoffs among the equipment characteristics, manpower availability and characteristics, mission effectiveness, and LCC.

Inputs which will drive the DAIS training model will include: descriptions of knowledge elements and skills needed in DAIS equipment maintenance; descriptions of the tasks performed in terms of criticality, difficulty, and frequency; available methods and media of instruction; and the costs associated with these various alternatives.

Table 1 INTERFACE BETWEEN LSC MODEL AND MTA

LSC Input Required	MTA Output Provided
No. of LRUs per subsystem	Direct output of MTA data banks
No. of a given LRU per subsystem	Direct output of MTA data banks
No. of SE end items	Direct output of MTA data banks
Utilization rate for SE	Equivalent to the maintenance man hours (MMH) or a portion thereof for each maintenance task. MMH is a direct output of the MTA data banks.
Fraction of operational failures repairable at flightline (per LRU)	Direct output of MTA data banks
Mean flying time between maintenance actions per LRU	Failure clock in MTA data banks is in terms of mean sorties between maintenance actions (MSBMA). Conversion is in terms of flying hours per sortie.
Fraction of removals repaired at base level (per LRU)	Direct output of MTA data banks
Mean time to repair per LRU at base level	Direct output of MTA data banks
Mean time to repair per LRU at flightline	Direct output of MTA data banks
Mean time to remove and replace a given LRU at the flightline	Direct output of the MTA data banks
Fraction of removals sent to depot for repair	Direct output of the MTA data banks
Scheduled maintenance man hours and scheduled maintenance intervals	Schedule maintenance is a small fraction of total avionics maintenance. Fractional increments will be added to unscheduled maintenance values (as appropriate) to account for this.

Clearly, the set of inputs described above will be developed from many sources. However, a clear interface exists between the MTA and the DAIS training model in terms of the task descriptions as well as type of skills and skill levels required of the maintenance specialist/technicians. The skill and knowledge inputs will result from a training analysis which will be part of the DAIS training model development. However, the training analysis uses the MTA as a data source for the types of maintenance tasks required, their frequency, and the amount of manpower needed to perform the maintenance activities.

INPUT REQUIREMENTS

Satisfying the outputs cited in the previous paragraphs required that a study be conducted of available relevant data and their sources. Data of different types, i.e., design data, reliability data, maintainability data, human resources data, etc., are generally available only from different sources. A listing of individual data categories and their sources is shown in Table 2. In general the required data was found to exist in technical orders (TOs), specifications, and planning documents available through contacts with the appropriate system project offices (SPOs). A major input resulted through access to data in Air Force and Navy maintenance data collection (MDC) systems. The required Navy data were provided as a result of contacts with Naval Air System Command (NAVAIR) through their access of the 3M system. AFM66-1, KO-51, and D056 were the sources of Air Force data (see footnote Table 2).

The required inputs for the current DAIS MTA can be classified in six categories as shown in Table 2. The first of these encompasses the basic R&M network data for the subsystems used in the current DAIS conceptual design configuration. This involved exercising the AF and Navy MDC systems to obtain data for those equipments already in inventory. R&M data for the core element portion of the avionics suite was based on specifications and relevant experience with the AFAL DAIS integrated test bed.

Completing the maintenance task networks required additional data besides the R&M for the prime avionics equipment. SE information was needed in order to identify the SE required for the DAIS and to account for its utilization. Much of this was obtained from TOs. An additional source of information was the cross reference listing for communication and navigation which allows a direct correlation between individual items of prime avionics and the SE used in their maintenance (Ref. 12).

Table 2 MTA INPUT DATA

Data Category	Data Elements	DATA SOURCE: Gov't. Agency	DATA SOURCE: Military Data System	DATA SOURCE: DRC Generated
Subsystem R&M data (baseline configuration) A-7D, F-15, A-7E, F-14, A-10	• maintenance actions/flight hour • how malfunctioned codes • action taken codes • maintenance man-hours/maintenance action (MMH/MA) • maintenance man-hours/action taken code (MMH/ATC)	For A-10: A-10 SPO	For A-7D: extended -11 forms AF maintenance data collection systems* (MDCS) For F-15: AF MDCS For A-7E, F-14: Navy 3M system	
Characteristics of new sensors and core elements	• subsystem descriptions • functional block diagrams • CITS capability • failure modes • reliability predictions	AFAL test bed experience; specifications	Similar systems in the inventory (AF MDCS)	conceptual design configuration report (AFHRL-TR-76-59)
Support equipment (SE) data	• name of SE • purpose of SE • Army-Navy (AN) nomenclature	A-7D TOA and configuration (SPO) F-15 TOA (SPO) A-10 TOA (SPO)	subsystem TOs, cross-reference listing for comm. & nav.	conceptual design configuration report (AFHRL-TR-76-59)
Human resources data	• maintenance man-power required by task • skill levels • availability and use of job performance aids (JPA)	AFHRL, TAC field sites	AF MDCS	Judgmental
R&M data from comparable subsystems (F-15, F-14, C-5A)	• reliability • MTTR • MMH/MA • how malfunctioned • action taken code		AF MDCS Navy 3M	
Software tasks	• software maintenance			Judgment based on similar systems

*Elements used in the AF maintenance data collection system included AFM66-1, and logistics support cost products (KO-51) and reliability/maintainability summary products (DO-56) of the Increase Reliability of Operational Systems (IROS) program implemented per AFLCR 400-16 and AFR 400-46.

Human resources data of various types were needed for the MTA. Manpower utilization by Air Force skill category (AFSC) was extracted from AFM66-1 sources via the AFHRL maintenance manpower modeling system (MMMS) pre-processing programs. The skill levels (as distinguished from the aforementioned skill categories) were acquired through discussions with Air Force field personnel. Skill levels are not generally reported to the AFM66-1 data system and these discussions were aimed at learning what is current practice in the field.

The human resource factors cited above satisfy the objectives of the MTA as described in Section II. When combined with the specific skills and knowledge elements to result from the training analysis and the alternative maintenance concepts appropriate to the DAIS, they will serve as inputs to the DAIS training model data bank. This will allow tradeoffs among alternative training approaches and training programs.

In some cases it was judged desirable to verify data on the selected subsystems by comparing this data with similar information from comparable subsystems. Data from subsystems contained in the F-15, F-14, and C-5A were studied and compared with the data for the subsystems used in the current DAIS conceptual design configuration. Reconciliations were made where necessary.

Software maintenance, as currently performed by military personnel at the organizational and intermediate maintenance levels has been included in the current MTA data bank as an integral part of the processor maintenance networks. This includes only that portion of the software maintenance involved in the servicing of the processor and peripheral equipment that result from design changes implemented in the software.

The term "software maintenance" is commonly used to mean the engineering aspects associated with the determination that a software problem actually exists, the programming effort expended in redesigning and recoding the program, the debugging of the program, and the subsequent insertion of a new tape into the peripherals or a new set of instructions into the computer memory. The last of these tasks, the physical change to the avionics processing system, is

handled by military maintenance technicians. The resources utilized in this effort are reported as part of the routine MDC data reporting activity. It is these hardware-related software tasks and resource utilizations that appear in the current DAIS MTA data bank. The numerical values used were obtained through information gained on the A-7D and F-15 computers. These values have been integrated with the data associated with the normal hardware maintenance requirements for the DAIS processor.

Traditionally, the engineering and programming aspects of what is considered software maintenance have been accomplished by either contractor or military personnel outside the field maintenance system. Thus, while the costs associated with these activities have a definite influence on the LCC of the current DAIS conceptual design, they have no bearing on the utilization or training of maintenance manpower within the context of the maintenance concepts currently in practice. Since, however, a goal of the DAIS LCC Modeling System is to provide the Air Force with an improved capability to investigate alternative maintenance concepts, it is recognized that future systems should admit of the possibility that the program design and coding be accomplished in the field. This would then involve both the utilization and the training of the required manpower. Therefore, although costs for the engineering and programming portions of this activity will be lumped with other depot-level maintenance costs in the LSC model, provisions will be made to examine these cost elements, the utilization of resources, and the consequent requirement for manpower training in terms of their potential as part of the field maintenance activity.

CHARACTERISTICS OF THE MILITARY DATA SYSTEMS USED

Both the AF and Navy MDC systems were used as major sources of data. The following is a brief description of the outputs available from these systems.

- AF MDC System (AFM66-1)

Maintenance Data Collection Record

The Maintenance Data Collection Record, AFTO Form 349, is used by Air Force specialist/technicians to report each maintenance action in the field. It provides all pertinent maintenance information such as equipment being repaired, action being taken, labor category,

and time to repair. The data is aggregated by the MDC system in accordance with AFM66-1, and a number of data systems operate on this large data base. These data systems include DO-56, KO-51 and MMS pre-processor data outputs.

DO-56

The DO-56 system is called a "demand system" by AFLC, which means that outputs can be requested for specified conditions. For each aircraft subsystem over a period of time it contains:

Operations data
- percent sorties aborted in flight for material failure
- percent sorties aborted on ground for material failure

Reliability data
- total failures/1000 flight hours
- total failures/sortie
- percent failures discovered before flight
- percent failures discovered in flight
- percent failures discovered between flights
- items not repairable this station (NRTS)/1000 flight hours

Maintenance data
- manhours/1000 flight hours
- manhours/sortie
- shop repair actions
- bench check or repair
- other shop actions

KO-51

The KO-51 weapon system effectiveness program and models segment is a "routine system" which means that its only outputs are standard data products that are distributed on a periodic basis. The PN3L product of KO-51 is a source of the following type of information:

Basic data
- number of aircraft
- total flight time
- average flight time

Operations data
- utilization (flight hours/month)
- landings/flight hour
- turn around time

- Navy MDC System

3M

The two data products selected from the 3M MDC system to provide data on the A-7E, F-14A, and A-6 weapons systems were report numbers MSO4790. A2142-01 and MSO4790. A2245-01. These two reports are distributed quarterly for a six-month data base and provide, respectively, aircraft (on equipment) maintenance activity and intermediate maintenance level (shop) activities (IMA). Specifically, these two reports provide the data elements listed below by work unit code (WUC).

Fleet Weapon System Reliability and Maintainability (Report MSO4790. A2142-01)
Statistical summary tabulations

- total maintenance actions
- mean flight hours between maintenance actions (MFHBMA)
- total failures
- number of failures repaired at organizational level
- mean flight hours between failures
- manhour expenditures
- assembly and system summaries
- elapsed maintenance time per maintenance action

3M Aviation Component Repair Report (Report MSO4790. A2245-01)

- total items processed
- number of no defects
- number of items repaired
- number of items NRTS
- average item turn around times
- average item awaiting parts time
- average IMA manhour expenditure and elapsed maintenance time per repaired item
- average organizational level manhours and elapsed maintenance time per item processed
- average IMA manhours per no defect item

SUMMARY

This section has described the manner in which both output and input requirements were established for the current MTA. Output requirements were defined by the needs of the users of the MTA, i.e., other LCC modeling system elements including the AFHRL MMMS. Input data requirements were identified to satisfy these needs via the MTA. Major sources of input data were the Air Force MDC and Navy MDC systems, planning documents, and technical orders.

With the study requirements established, the next step is a detailed discussion of the methodology used in performing the MTA and the results achieved.

IV. CONDUCT OF THE CURRENT DAIS MAINTENANCE TASK ANALYSIS AND DATA BANK DEVELOPMENT

METHODOLOGY

There are essentially three basic techniques for arriving at reliability and maintainability (R&M) parameter values of new avionics systems: prediction, demonstration, and field data techniques. Our approach consists of a combination of all three.

Briefly stated, the prediction technique uses estimates based on analytical methods which examine such things as parts counts, tabulated experience data, failure modes and effects analysis, task time estimation, etc. These techniques are described in MIL-HDBK-472, Maintainability Prediction, and MIL-STD-756A, Reliability Prediction.

The demonstration technique uses time and motion study methods to predict task times. This requires the actual measurement of time required to perform task simulations with breadboard or brassboard designs and eventually the equipment itself when MIL-STD-471, Maintainability Demonstration, is invoked. This is useful during the engineering model design period as a supplement to the prediction technique. It can then be used to evaluate any excessive maintenance task time highlighted by the prediction technique.

The field data technique is actually a form of the demonstration technique. However use is made of specific frequency of occurrence and task time data derived from maintenance experience for the same type of task on similar equipment under similar maintenance conditions.

Of the three basic techniques, the field data technique is the best because it reflects the real operational factors of the systems in their operating environment. Since this technique uses actual data, it will usually be more acceptable to the equipment designers and can thereby have more influence on the design. For these reasons plus the fact that considerable amounts of applicable field data were available, this method was chosen as the primary means of predicting the R&M parameter values in this maintenance task analysis (MTA). When it was available, the MTA used field data of the actual subsystems or

comparable subsystems for the non-DAIS avionics equipment. When such field data did not exist, e.g., for the DAIS core elements, field data for comparable subsystems or portions thereof were utilized. In this event, the available field data was augmented by prediction techniques. The prediction techniques chosen were those that rely heavily on engineering judgment and maintenance experience; namely, task time estimation and failure modes analysis.

The first step in this approach was to determine the extent to which field data could be utilized in quantifying the R&M parameters for a given subsystem. If the subsystem was in the inventory, the field data were directly applicable. If not, an engineering analysis was conducted to define the equipment design characteristics. These characteristics were compared to systems in the inventory. If portions of the equipment were the same as subsystems in the inventory (both subsystems having a common or functionally similar line replaceable unit (LRU), for example), then the R&M data for that common LRU were applicable. When the new system was substantially different from systems in the inventory, engineering analyses were conducted to quantify the R&M parameters. These engineering judgments were then tempered by whatever field data was available.

The results were evaluated by experienced maintenance personnel who have performed maintenance on equipment of a similar design. This insured that, regardless of the method used to perform the MTA, no pertinent maintenance problems would be overlooked.

DATA COLLECTION

Data collection was initiated by contacting the various data sources and processing the available data. The principal data products utilized are tabulated in Table 3. Tabulation is by subsystem and function.

The primary data source was the USAF maintenance data collection (MDC) system governed by AFM66-1. The data products which were utilized from this large data base include D056, K051, and the Maintenance Manpower System (MMS) pre-processor data outputs.

DRC queried the D056 system for avionics data on the A-7D, F-111E, F-15 and selected C-5 A subsystems. The D056B5527 output proved to be the most useful of the D056 data products for this study.

Table 3 – INPUT DATA SOURCES

	SUBSYSTEMS			DATA SOURCES USED							
	Work Unit Code	System Function	Representative Sub-System Nomenclature	Technical Order	D056	K051	LCOM Ext. 11	MMS	Navy 3M	Specifications	Other
SENSORS	51A00	Flight Instruments	A-7D	1A-7D-2-10	X	X	X	X			
	51B00	Navigation Instruments	A-7D	1A-7D-2-10	X	X	X	X			
	61A00	HF Radio	AN/ARC-123	12R2-2ARC123-2(&-22)	X	X					
	62A00	VHF-FM Communications	FM-622A	12R2-4-90-2	X	X	X	X			
	63510	Data Link	AN/ASW-25	16-30ASW25-1					X		
	63A00	UHF Radio Set	AN/ARC-51BX	12R2-2ARC51-2	X	X	X	X	X		
	63B00	Auto Direction Finder	AN/ARA-50	12R1-2ARA50-2	X	X	X	X	X		
	64A00	Intercommunications	AN/AIC-26	12R2-2AIC25-2	X	X	X	X	X		
	65A00	Transponder Set	AN/APX-72	12R4-2APX72-2	X	X	X	X	X		
	69A00	Speech Security System	TSEC/KY-28	1A-7D-2-12	X	X	X	X	X		
	71A00	Heading Mode Sys. (HSI)	AN/AQU-6/A	1A-7D-2-18	X	X	X	X			
	71B00	TACAN Set	AN/ARN-52	12R2-2ARN52-12	X	X	X	X	X		
	71C00	Radio Receiving System	AN/ARN-58	12R5-2ARN58-2	X	X	X	X			
	72A00	Radar Altimeter Set	AN/APN-141	12P5-2APN141-2	X	X	X	X	X		
	72B00	Radar Beacon Set	AN/APN-154	12P5-2APN154-2	X	X	X	X	X		
	73A00	Forward Looking Radar	AN/APQ-126	12P2-2APQ126-2	X	X	X	X	X		
	73C00	Air Data Computer	CP-953A/AJQ	5F5-4-21-3	X	X	X	X	X		
	73F00	Inertial Measurement Set	AN/ASN-90	5N16-3-6-2	X	X	X	X	X		
	76E00	Radar Homing & Warning Syst.	AN/ALR-46	12P3-2ALR46-2	X	X					
	77A00	Strike Camera System	KB-18A	10A1-6-6-2	X	X	X	X	X		
CORE ELEMENTS	7WA00	Electronic Display Group			X	X				DHB-CD-7	
	7WB00	Special Purpose Displays			X	X				DHB-CD-6 DHB-CD-8	Appendix D to FY11757510260
	7WC00	Display Controls			X	X				DHB-CD-1	
	7WD00	Mass Memory Unit			X	X				DHB-CD-11	
	7XE00	Multifunction Controls			X	X				DHB-CD-5 DHB-CD-4	
	7XF00	Dedicated Controls			X	X				DHB-CD-10	
	7YA00	Processor			X	X					Attachment No. 2 to F33615-75-R-1154
	7ZA00	Bus Control Interface Unit			X	X				SA301300B	
	7ZB00	Remote Terminal Unit			X	X				SA301402	Attachment No. 1 to F33615-75-C-1180

Data from the K051 weapon system effectiveness program and models segment was used to derive the approximate number of flight hours per sortie (FH/Sortie) by using the flight hours/landing. In the case of the A-7D, this method gave the FH/Sortie as 1.7. This number was used as a constant to convert the equipment mean flight hours between maintenance actions to mean sorties between maintenance actions.

The most valuable inputs available for assessing human resource utilization in field maintenance are the data products of AFHRL's MMMS. The input to the MMMS is the base-level tape, which is also the input to the MDC system. The MMMS pre-processing programs extract pertinent data and perform editing, processing, and formatting functions on it. The results are recorded in the form of networks or the so-called extended -11 format. The maintenance task networks of the DAIS MTA are based on the extended -11 format. Existing MMMS pre-processor outputs provided current data for the A-7D subsystems. The R&M data included the following:

Reliability data

- mean sorties between maintenance actions (MSBMA)

Maintenance data

- percent scheduled maintenance
- percent unscheduled maintenance
- percent manhours bench checking
- percent manhours troubleshooting
- percent flightline maintenance
- percent shop maintenance

Task data

- type of equipment
- time spent performing
- crew size required to perform
- AFSC distribution within each crew
- frequency of task
- kind of task
- probability of task occurrence

The A-7D was chosen as an aircraft whose functional characteristics represent those of a current CAS weapon system. The subsystems of the A-7D provided the bulk of the data needed. The A-7D data were supplemented, as necessary, with data from other Air Force and Navy weapons systems. The F-111 provided HF radio data for the

ARC-123. Information for the ASW-25A Data Link was obtained from the A-7E. These are examples of subsystems that form part of the current DAIS conceptual design but exist currently in aircraft other than the A-7D.

F-15 field data, although limited, proved useful as a source of data on subsystems similar to the DAIS core elements. Another source of R&M data on subsystems with design requirements similar to those of DAIS core element subsystems was the C-5A aircraft. In particular, the C-5A malfunction analysis detection and recording (MADAR) system has a number of LRUs with functional requirements similar to those of certain DAIS units.

The Navy's 3M MDC system provided data on the A-7E, A-6, and F-14 weapons systems. The similar configuration of the Navy A-7E to the Air Force A-7D made possible a direct comparison of some of the R&M data. This comparison served as a means of verifying the accuracy and consistency of the data sources. With few exceptions, the MFHBMA for the subsystems compared were within 30 percent of each other. This degree of consistency was judged acceptable in view of the diverse sources of these data and the resultant dissimilar methods used in testing and reporting failures and maintenance actions. The cause of the few larger disparities was either accounted for or will be during the course of subsequent analyses or field visits.

A complete list of documentation used is contained in Appendix A including data base outputs and reports (including the dates of their applicability), DAIS specifications, and technical orders/manuals.

DATA RECORDING

Pertinent R&M data elements were extracted from these various reports and recorded on worksheets to facilitate their analysis. These worksheets are part of an MTA work package which, together with the data bank, constitutes the current DAIS engineering data base. A work package was prepared for each avionics subsystem in the current DAIS conceptual design configuration. Included in these MTA work packages are the following items:

1. conceptual design work package
2. MTA data package
   - extracts from TOs
   - R&M particulars
   - maintenance requirements
   - WUC lists
   - SE lists
3. MDC reliability and maintainability extracts
4. failure modes data sheet
5. network schematics
   - current non-DAIS
   - current DAIS
6. equipment characteristics worksheets
7. analysis and status worksheets

SYNTHESIS OF R&M FACTORS

Synthesis of R&M factors, in this context, means the estimation of maintenance task parameter values for the LRUs and subsystems comprising the current DAIS conceptual design configuration. For the sensor portions of the avionics suite existing equipments had been selected and partitioned. The method used in the synthesis for the resulting subsystems was to modify the appropriate maintenance task parameter values in accord with predictable changes in the reliability, and test and repair times for the resulting hardware configuration. For the core elements, since no existing subsystems could serve as a baseline, parameter values were estimated based on R&M history of comparable equipments in the field. These values were modified in accordance with the functions and utilization of the hardware anticipated for the DAIS core elements.

Since a requirement exists that the MTA interface and be directly compatible with the AFHRL MMMS it was decided that the most useful format for the MTA data banks would be that of the extended -11 card as well as its visual representation, i.e., the maintenance task network diagram. The network diagrams will be used to describe the manner in which the synthesis was conducted. An example is given also to demonstrate the actual application of the procedure to a specific subsystem.

The synthesizing process was initiated by using all available sources of R&M parameter values. Field data were needed for each of the subsystems chosen as the baseline avionics design for a CAS mission. Previous Air Force efforts were used whenever possible. In particular, there were a number of A-7D maintenance networks in extended -11 format which had been prepared in 1972 and updated in 1974 that provided a nucleus for the synthesis. These networks were reviewed in the light of more recent R&M data and updated accordingly.

The remainder of the subsystems were analyzed by using recent R&M data from other weapons systems in the inventory, the sources of which were described previously. The set of R&M factors derived from these efforts resulted in a baseline MTA data bank.

The next step in the synthesizing process involved an analysis of the subsystem configurations resulting from the partitioning. Because of the transferral of specific subsystem functions to the core elements, both reliability and maintainability values will change. The modification of these values to conform to the partitioning of the hardware is described below in the paragraphs entitled 'Partitioning of R&M Factors'. It is valuable, however, at this point in the report to describe the extended -11 format and its pictorial representation, the maintenance task network diagram.

Maintenance Task Networks

The networks concept was developed by the Air Force to satisfy the needs of the AFHRL MMMS (Refs. 1, 2). The MMMS uses special pre-processing and post-processing programs in conjunction with the Logistics Composite Model (LCOM) as a maintenance manpower simulation model (Refs. 2, 3, 4, 5). The current DAIS MTA data bank, developed as part of this effort has been delivered in a form which permits direct loading into the AFHRL MMS model. That form is the extended -11 card. The maintenance task networks (MTN) provide a visualization of the coded data which appear on the extended -11 cards. These MTNs are useful as a tool to understand and appreciate the methodology used and the results obtained from the MTA.

Figure 5 is a simplified MTN diagram indicating only the task flow. The MTN in this graphical form is well suited to display the maintenance tasks that have to be accomplished to return a subsystem to operable condition and the order in which they are to be done. The "on equipment" tasks are accomplished at the organizational level and pertain to the entire subsystem. The "off equipment" tasks are shop tasks on the LRUs and are usually conducted at the intermediate maintenance level.

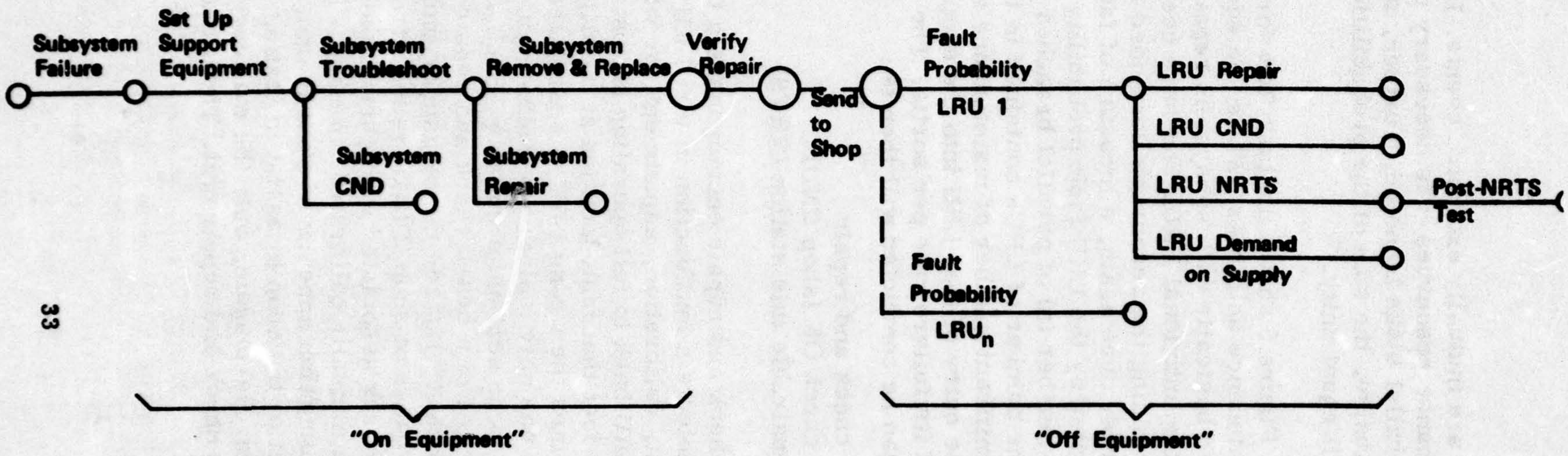
The maintenance process is initiated by a "squawk" or indication on the part of the air crew or maintenance personnel that a malfunction exists. Whether this proves to be an actual failure or is a human (or equipment) error which will later result in a "cannot duplicate" (CND) is unimportant from the point of view of the MTA since it results in a demand for maintenance resources. The subsystem failure frequency is therefore based on these "squawks" which trigger the subsequent maintenance activities.

The initial maintenance activity is to set up the necessary test equipment and power sources at the flightline and exercise the subsystem that has been "squawked". If, in fact, a failure has occurred a troubleshooting activity will take place in order to locate the cause of the malfunction. In some instances, the apparent failure cannot be duplicated and the maintenance activity will terminate as a CND disposition.

The troubleshooting activity carried to its conclusion isolates the malfunction to a hardware entity, normally a line replaceable unit (LRU). Depending on the nature of the malfunction it may be necessary to remove the malfunctioning LRU (or LRUs) and send them on to the field shop for repair. If this is done, the aircraft is put back into service by replacing the unit(s) removed with functioning LRUs from the supply stock. Alternatively, it may be possible to effect the needed repair on the aircraft. In either case, a verification process is used to provide assurance that the procedure used has, in fact, corrected the problem.

Two sets of parallel tasks have been noted above for the "on equipment" maintenance. The checkout of the subsystem may, in the first case, result in a troubleshooting activity in order to locate a malfunction detected by the test equipment and flightline technician. On the other hand, if no malfunction is detected, the CND disposition is invoked. Similarly, the repair of the malfunction may be accomplished through a remove and replace action (and subsequent shop activity on the removed LRUs) or by an on-aircraft repair. In each

Figure 5
SIMPLIFIED MAINTENANCE TASK NETWORK
(Indicating Only the Task Flow)



MERITS

- standardized form—suited for describing flow oriented process
- graphical form—more understandable (more precise and less ambiguous) than English text
- computerized form—facilitates assessments, modifications and interfacing networks

case, the parallel tasks are mutually exclusive events. In terms of the utilization of maintenance resources it is necessary that the probabilities of these parallel tasks be noted. Further, since the events are mutually exclusive, the sum of the probabilities of each pair of parallel tasks will equal unity.

The right side of Figure 5 shows the task flow for "off equipment" or shop maintenance activities. While "on equipment" maintenance is concerned basically with subsystem repair, shop maintenance deals with the individual LRUs that have been removed from the aircraft. Determining the resources demanded at this maintenance level requires, once again, a measure of failure frequency. This is indicated by the LRU fault probability given in failures per sortie. The number (n) of parallel branches in this part of the MTN is equal to the number of LRUs contained in the subsystem that have any significant number of maintenance actions. Each branch indicates the entry of that LRU into the shop maintenance activity in terms of its failure rate per sortie. The possible maintenance tasks that can be conducted will then be:

a) LRU bench check and repair
b) LRU benoh check OK (shop CND)
c) LRU not repairable this station (NRTS)

The LRU bench check and repair encompasses a troubleshooting activity which detects a malfunction in that LRU and a subsequent part replacement, calibration, adjustment, or whatever is necessary to bring the LRU back to full operating status. The CND activity results from the fact that fault location at the flightline is imperfect so that sometimes the wrong LRU is sent to the shop. Often the flightline procedures can only isolate the malfunction to a group of LRUs so that all have to be sent on to the shop. Such a circumstance would result in the reporting of a bench check and repair on the LRU that had actually failed with CNDs for the remaining units of the group. Another possible cause of shop CNDs results from the operating and test procedures associated with certain pairs or groups of LRUs which have been mutually calibrated, in effect "married" to one another. When a malfunction appears to exist in one, the other or others must accompany it to the shop to assist in testing and possible subsequent re-calibration. Here again, only the malfunctioning LRU will be shown as a bench check and repair unit. The others will be tallied as CNDs.

The NRTS disposition is used to describe the maintenance activity which results in shipping a unit to another maintenance activity where greater capability exists for certain types of testing and/or repairs. Usually this is the depot where more sophisticated test equipment and higher skill levels have been pooled. The units shipped may be either LRUs or shop replaceable units (SRU). If the shop has no capability to maintain a specific LRU it will be NRTS to depot. In other instances, repairs can be effected by removing and replacing malfunctioning SRUs which, in turn, cannot be serviced at that location. The SRUs will then be NRTS-dispositioned to the appropriate depot.

A specific example of a complete MTN is shown in Figures 6 and 7 for the current DAIS high frequency (HF) radio. The on equipment or flightline maintenance task flow and accompanying R&M data are shown in Figure 6. Off equipment or shop maintenance is covered in Figure 7. This subsystem was derived by the partitioning of the AN/ARC-123 radio. Of the original set of LRUs which comprise the AN/ARC-123, the control unit and the antenna coupler control were transferred to the DAIS core. The data shown in Figure 6 represent the subsystem R&M factors for the remaining sensor portion of this partitioned subsystem. Figure 7 shows the task flow and R&M data for the shop maintenance of the reciever/transmitter LRU. Similar MTNs exist for the remaining LRUs, i.e., the amplifier, power supply, the antenna coupler, and the variable capacitor.

At each node or stage of the maintenance process a set of codes is shown which specify to the computer the task processing sequence and the data germane to the individual tasks. Above each node is shown a unique number which defines that node for that subsystem or LRU and is used to sequence the tasks to the computer. The data indicated at the nodes themselves include the following, as appropriate, to the event or the task performed:

- Event or task code defining the tasks needed to accomplish the corrective work. The codes used are:

  Flightline task codes
  F - failure clock. This controls the frequency with which the succeeding maintenance tasks will be performed. The maintenance action interval used is the number of mean sorties between maintenance actions (MSBMA)
  A - task to get and to set up powered SE

EXAMPLE: ON EQUIPMENT TASK NETWORK FOR WUC 61A00

Figure 6

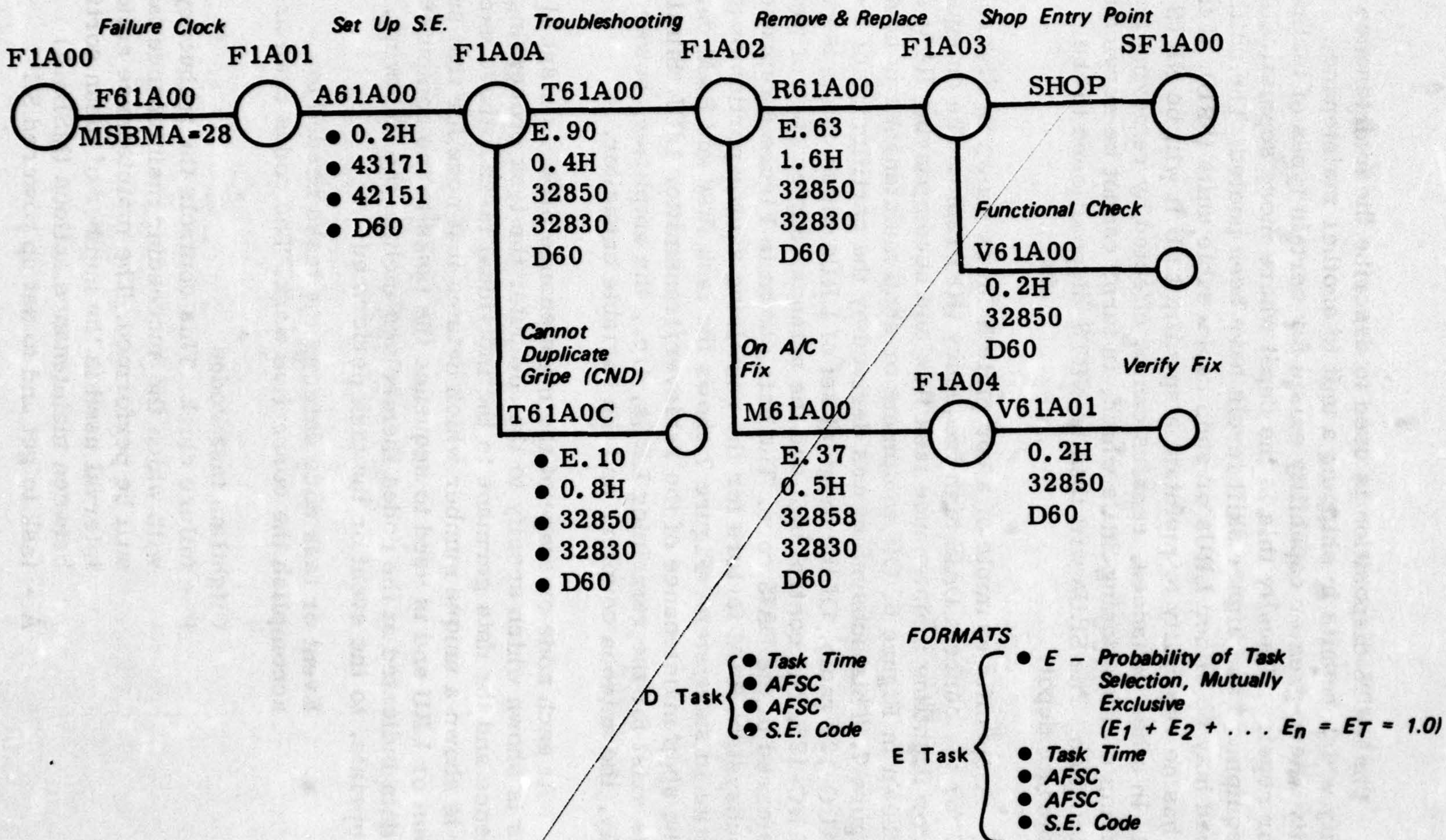
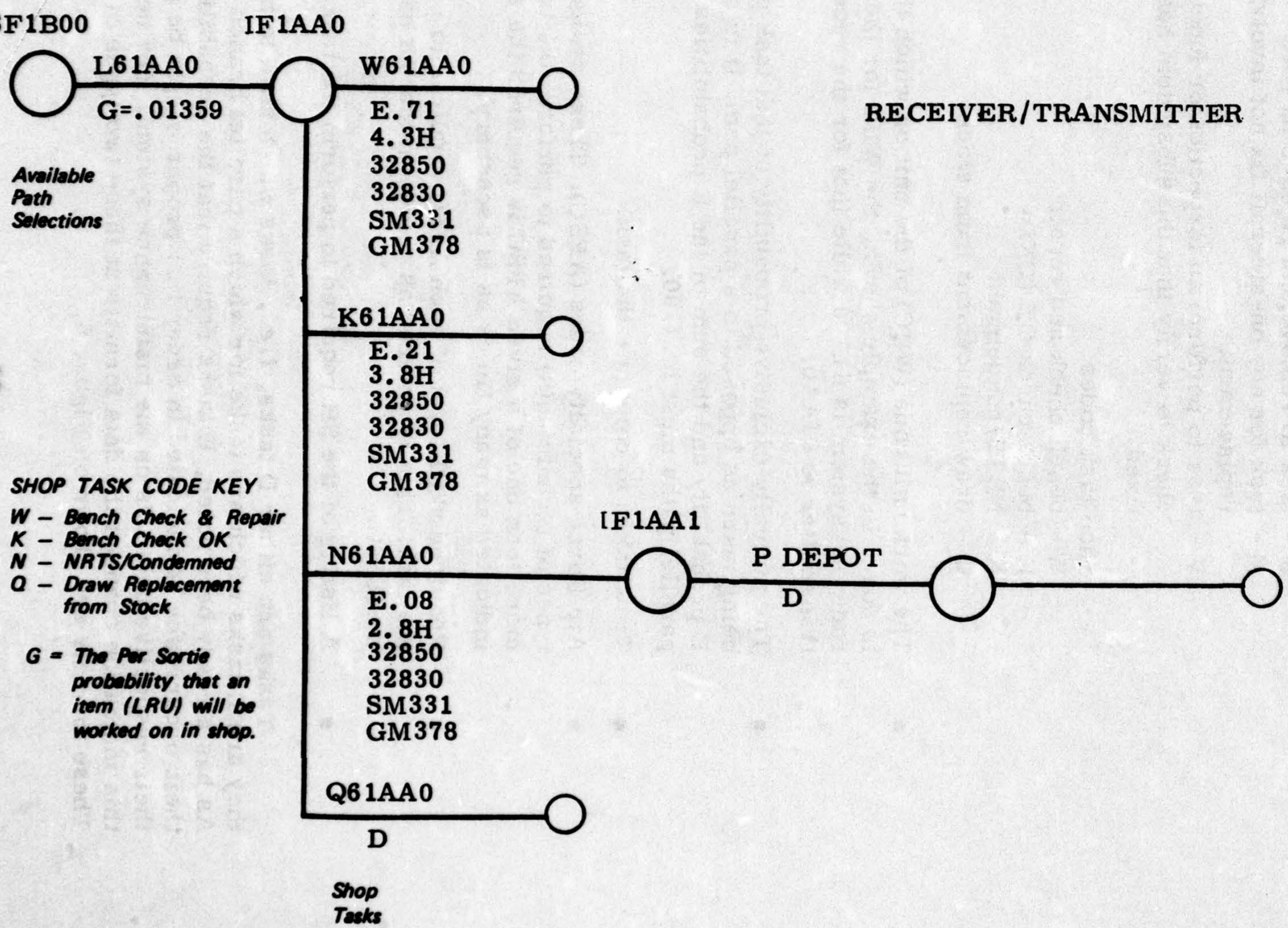


Figure 7

EXAMPLE: OFF EQUIPMENT TASK NETWORK FOR WUC 61AA0



SHOP TASK CODE KEY

W – Bench Check & Repair
K – Bench Check OK
N – NRTS/Condemned
Q – Draw Replacement from Stock

G = The Per Sortie probability that an item (LRU) will be worked on in shop.

T - task to troubleshoot the subsystem
T_C - troubleshooting, cannot duplicate (CND) problem
R - task to remove and replace an LRU
M - task for any on-aircraft fix not involving LRU replacement
V - task to perform an inspection or functional check to verify that the subsystem has been fixed

Shop task codes
W - bench check and repair
K - bench check OK (CND)
N - NRTS/condemned
Q - draw replacement from stock

- The work unit code (WUC) of the unit on which the work is done. In the example shown, the WUC for the HF radio subsystem is 61A00 while that for the receiver/transmitter is 61AA0.

- The mutually exclusive probability of that task path being taken as opposed to a parallel path. It is called an E probability and the sum of the E probabilities for the parallel paths must be 1.00.

- Time taken to complete the task.

- Air Force specialty codes (AFSC). These designate the types of technician(s) required to perform the task. If more than one of a given AFSC is required the code is indicated as many times as is necessary.

- Required skill level of each AFSC required to perform the task. This is entered as a code in the 4th position on the AFSC.

- A listing of the SE required to perform the task.

Tasks are either D tasks, i.e., tasks which have to be done or they are E tasks which are tasks for which a parallel branch exists. As has already been noted, E tasks require that the probability of their occurrence be indicated in order that proper weight be given to their respective demands on the maintenance system. The need for this indication changes the data formats at these two types of nodes. These formats are shown on Figure 6.

Four other codes or code combinations, all of which appear in the shop maintenance network of Figure 7, require explanation. The first of these is the L code which designates the probability of a shop repair on a given LRU. The number associated with this event is known as the G probability of occurrence. These probabilities, in contrast to the E probabilities, are not mutually exclusive. This is to account for the fact that the process of fault isolation at the flightline is an imperfect one. Sometimes two or more LRUs are removed and sent to the shop simply because uncertainty exists as to which one may have actually malfunctioned. While only one LRU may ultimately be repaired (or perhaps NRTS) CND maintenance actions are required to disposition the remaining LRUs.

The Q event is a dummy task that represents drawing a spare LRU from supply to satisfy the aircraft need.

The PDEPOT task code follows a NRTS action and is used to represent a standard depot turn around time (TAT). The absence of a PDEPOT after a NRTS indicates the LRU is a throwaway item or is condemned (not economically repairable).

A K-coded task following the PDEPOT task indicates that the LRU is bench tested upon receipt from supply before being used as a rotatable spare.

The selection of the major tasks to be included in this model of the maintenance of an avionics system was based on an evaluation of the requirements of the elements of the AFHRL MMMS which interface with the MTA, as well as the other components of the DAIS LCC modeling system. The following criteria had to be satisfied:

- Will the tasks satisfy the needs of the models they will feed?
- Are the tasks separable (mutually exclusive)?
- Are the tasks too broad in scope?
- Is field data available to provide the resources (men, material, time) required for each task?

Because of the specific requirement that the DAIS LCC modeling system components be compatible with the AFHRL MMS, the requirements of the latter were examined first. Analysis of the task codes used in the AFHRL MMS proved that, with one exception, they satisfied all these criteria. The sole exception was the code for

designating the access of equipment. DRC chose not to include this code in the MTN for a number of reasons: (1) access time is dependent on the aircraft design and exact equipment location which cannot be provided by our DAIS conceptual design configurations; (2) there is no action taken code (ATC) in the Air Force or Navy maintenance record systems that breaks out access time; technicians presently record this access time as part of the overall job time requirements record. For the foregoing reasons (and since the access time is already included in all our recorded maintenance data) it was decided not to attempt to break it out as a separate task in the MTNs.

The network task codes are shown in a cross-reference listing in Table 4 to show their relationship to the number and type of ATC that are reported in the AF66-1 and Navy MDC systems. The network task codes chosen to identify all the tasks necessary to maintain a subsystem in this MTA are sufficient to categorize all the ATCs with the exception of those involving cannibalization which were not used. The MMMS pre-processing programs were designed to extract these field MDC data in this fashion thus making possible its direct use in the maintenance task networks (Ref. 3).

Extended -11 Format

The MTNS contain all the information and provide a ready visualization for the flow of task data into the computer. The actual input to the computer is the extended -11 form shown in Figure 8. The pages shown are a portion of the listing of the entire current MTA data bank. These pages contain the data elements for the HF radio discussed in the example of Figures 6 and 7. While the data forms are shown sorted on WUC number, within a WUC several cards must be positioned in the correct sequence. A four-digit sequence number has been added in columns 1-4 to aid in this sequencing. The format for the entire card is given in Table 5.

PARTITIONING OF R&M FACTORS

Sensor Partitioning

The conceptual design study, utilizing pre-defined selection criteria, partitioned the selected avionic subsystems into the current DAIS conceptual design configuration. The partitioning of an avionic

Table 4

TASK CODE CROSS REFERENCE LISTING

Network Task Code		66-1 Action Taken Code (3M Code if different from 66-1)	
Flight Line Tasks			
A	Set Up Support Equipment	—	
T	Troubleshooting	Y	Troubleshooting
T_C	*Troubleshooting, cannot duplicate (CND) problem*	H	Equipment Check-No Repair Required
		Y	Troubleshooting with a 799 code
R	Remove and Replace	R	Remove & Replace
		P	Removed
		Q	Installed
M	Maintenance on Equipment	F	Repair
		G	Repair &/or Replace minor parts (B)
		L	Adjust (None)
		J	Calibrated–No Adjust Required
		K	Calibrated–Adjust Required
		V	Clean (None)
		Z	Corrosion Repair
V	Verify Fix	X	Test/Inspect/Service (None)
Shop Tasks			
L	Probability of Shop Repair	—	
W	Bench Check & Repair	C	Bench Ck–Repair Deferred
		Y	Troubleshoot
		A	Bench Ck & Repaired (C)
		F	Repair (C)
		G	Repair &/or Replace minor parts (B)
		J	Calibration–No adjust required
		K	Calibration–Adjust required
		L	Adjust (None)
		V	Clean (None)
		Z	Corrosion Repair
K	Bench Check OK	B	Bench Ck–Serviceable (A)
		X	Test/Inspect/Service
		799	No defect
		803	No defect–time change
		804	No defect–scheduled maintenance
N	NRTS/Condemned	D	Transferred to another base or unit but not to depot
		D(1-7)	Bench Ck–NRTS
		D(8)	Depot
		D(9)	Condemned
Q	Draw Replacement	—	

Figure 8

EXTENDED -11 FORMS

```
                   PRINTOUT OF:   CURRENT OAIS TASK ANALYSIS DATA BANK
F010                        H         51A00   FLIGHT INSTRUMENTS                   075
F020 E1A00 F51A00  E1A0A F     32 51A00 21
F030 E1A0A A51A00  E1A0B D        51A00 21     02 29L 143171 142153 1060
F040 E1A0B T51A00  E1A02 E     06 51A00 21     12 29L 132551 132531 1060   1SM565
F050 E1A0B T51A0C        E     12 51A00 21     14 29L 132551 132531 1060
F060 E1A02 R51A00  E1A03 E     44 51A00 21     17 29L 132551 132531 1060
F070 E1A02 M51A00  E1A04 E     56 51A00 21     12 29L 132551 132531 1060
F080 E1A03 V51A00        D        51A00 21     05 29L 132551 132531 1060   1SM565
F090 E1A04 V51A01        D        51A00 21     05 29L 1?2551 132531 1060   1SM565
F100 E1A03 SHOP   SE1A00 D        51A00 21
1010                        H         51A00   AIRCRAFT SYST INST                   075
1020SE1A00 L51AA0 IE1AA0 G 00267 51A00 23
1030IE1AA0 W51AA0        E     15 51A00*23     14 29L 132551 132531
1050IE1AA0 N51AA0 IE1AA1 E     05 51A00*23     08 29L 132551
1060IE1AA0 Q51AA0        D        51A00 21
1070IE1AA1 PDEPOT        D        51A00 23
2010                        H         51A00   COUNTING ACCELEROMETER & OTHER       075
2020SE1A00 L51AB0 IE1AB0 G 00023 51A00 23
2050IE1AB0 N51AB0        E    100 51A00*23     09 29L 132551
2060IE1AB0 Q51AB0        D        51A00 21
3010                        H         51A00   APPROACH ATTITUDE INDICATING SYS     075
3020SE1A00 L51AD0 IE1AD0 G 00421 51A00 23
3050IE1AD0 N51AD0 IE1AD1 E    100 51A00*23     09 29L 132551
3060IE1AD0 Q51AD0        D        51A00 21
3070IE1AD1 PDEPOT        D        51A00 23
4010                        H         51A00   PITOT STATIC SYST                    075
4020SE1A00 L51AE0 IE1AE0 G 00517 51A00 23
4030IE1AE0 W51AE0        E     03 51A00*23     15 29L 132551 132531
4040IE1AE0 K51AE0        E     00 51A00*23     12 29L 132551
4050IE1AE0 N51AE0 IE1AE1 E     09 51A00*23     10 29L 132551
4060IE1AE0 Q51AE0        D        51A00 21
4070IE1AE1 PDEPOT        D        51A00 23
F010                        H         51B00   NAVIGATION INSTRUMENTS               075
F020 E1B00 F51B00  E1B0B F    400 51B00 21
F030 E1B0B A51B00  E1B0A D        51B00 21     02 29L 143171 142153 1060
F040 E1B0A T51B00  E1B02 D        51B00 21     14 29L 132551 132531 1060
F060 E1B02 R51B00  E1B03 E     73 51B00 21     15 29L 132551 132531 1060
F070 E1B02 M51B00  E1B04 E     10 51B00 21     11 29L 132551 132531 1060
F071 E1B02 M51BA0        E     09 51B00 21     14 29L 153150 153130 1060
F080 E1B03 V51B00        D        51B00 21     07 29L 132551 132531 1060
F090 E1B04 V51B01        D        51B00 21     07 29L 132551 132531 1060
F100 E1B03 SHOP   SE1B00 D        51B00 21
1010                        H         51B00   REMOTE STBY ATT IND SYST             075
1020SE1B00 L51BA0 IE1BA0 D        51B00 23
1050IE1BA0 N51BA0 IE1BA1 E    100 51B00*23     13 29L 132551
1060IE1BA0 Q51BA0                 51B00 21
1070IE1BA1 PDEPOT        D        51B00 23
F010                        H         61A00   HF RADIO                             075
F020 F1A00 F61A00  F1A01 F     20 61A00 21
F030 F1A01 A61A00  F1A0A D        61A00 21     02 29L 143171 142151 1060
```

HF Radio

COPY AVAILABLE TO DDC DOES NOT PERMIT FULLY LEGIBLE PRODUCTION

Figure 8 (continued)

HF Radio

```
F040 F1A0A T61A00   F1A02 E    90 61A00 21     04 29L 132050 132030 1060
F050 F1A0A T61A0C         E    10 61A00 21     00 29L 132050 132030 1060
F060 F1A02 R61A00   F1A03 E    63 61A00 21     16 29L 132050 132030 1060
F070 F1A02 M61A00   F1A04 E    37 61A00 21     05 29L 132050 132030 1060
F080 F1A03 V61A00         D       61A00 21     02 29L 132050 1060
F090 F1A04 V61A01         D       61A00 21     02 29L 132050 1060
F100 F1A03 SHOP    SF1A00 D       61A00 21
1010                     H        61A00   RECEIVER/TRANSMITTER             D75
1020SF1A00 L61AA0 IF1AA0 G 01359 61A00 23
1030IF1AA0 M61AA0         E    71 61A00*23     43 29L 132050 132030 1SM331 1GM370
1040IF1AA0 K61AA0         E    21 61A00*23     39 29L 132050 132030 1SM331 1GM370
1050IF1AA0 N61AA0 IF1AA1  E    00 61A00*23     25 29L 132050 132030 1SM331 1GM370
1060IF1AA0 Q61AA0         D       61A00 21
1070IF1AA1 PDEPOT         D       61A00 23
2010                     H        61A00   AMPLIFIER POWER SUPPLY           D75
2020SF1A00 L61AB0 IF1AB0 G 01410 61A00 23
2030IF1AB0 M61AB0         E    76 61A00*23     52 29L 132051 132031 1SM331 1GM370
2040IF1AB0 K61AB0         E    17 61A00*23     31 29L 132051 132031 1SM331 1GM370
2050IF1AB0 N61AB0 IF1AB1  E    07 61A00*23     06 29L 132051 132031 1SM331 1GM370
2060IF1AB0 Q61AB0         D       61A00 21
2070IF1AB1 PDEPOT         D       61A00 23
3010                     H        61A00   ANTENNA COUPLER                  D75
3020SF1A00 L61BA0 IF1BA0 G 00472 61A00 23
3030IF1BA0 M61BA0         E    44 61A00*23     60 29L 132050 132030
3040IF1BA0 K61BA0         E    22 61A00*23     15 29L 132050 132030
3050IF1BA0 N61BA0 IF1BA1  E    34 61A00*23     20 29L 132050 132030
3060IF1BA0 Q61BA0         D       61A00 21
3070IF1BA1 PDEPOT         D       61A00 23
4010                     H        61A00   VARIABLE CAPACITOR               D75
4020SF1A00 L61BC0 IF1BC0 G 00495 61A00 23
4030IF1BC0 M61BC0         E    74 61A00*23   52  29L 132050 132050
4040IF1BC0 K61BC0         E    21 61A00*23   13  29L 132050 132050
4050IF1BC0 N61BC0 IF1BC1  E    05 61A00*23   15  29L 132050 132050
4060IF1BC0 Q61BC0         D       61A00 21
4070IF1BC1 PDEPOT         D       61A00 23
F010                     H        62A00   VHF FM COMMUNICATIONS SET        D75
F020 F2A00 F62A00   F2A0B F    41 62A00 21
F030 F2A0B A62A00   F2A01 D       62A00 21     02 29L 143171 142153 1D60
F040 F2A01 T62A00   F2A02 E    82 62A00 21     00 29L 132050 132030 1060
F050 F2A01 T62A0C         E    10 62A00 21     09 29L 132050 132030 1D60
F060 F2A02 R62A00   F2A03 E    67 62A00 21     12 29L 132050 132030 1060
F070 F2A02 M62A00   F2A04 E    33 62A00 21     11 29L 132050 132030 1060
F080 F2A03 V62A00         D       62A00 21     04 29L 132050 1D60
F090 F2A04 V62A01         D       62A00 21     02 29L 132050 1D60
F100 F2A03 SHOP    SF2A00 D       62A00 21
1010                     H        62A00   RECEIVER/TRANSMITTER             D75
1020SF2A00 L62AA0 IF2AA0 G 01535 62A00 23
1030IF2AA0 M62AA0         E    75 62A00*23     40 29L 132050 132030 1FMTS
1040IF2AA0 K62AA0         E    17 62A00*23     17 29L 132050 132030 1FMTS
1050IF2AA0 N62AA0 IF2AA1  E    00 62A00*23     31 29L 132050 132030 1FMTS
1060IF2AA0 Q62AA0         D       62A00 21
```

Table 5

FIELD FORMAT OF DATA ELEMENTS

Extended -11

Data Elements		Field Format			
Column	Title	Length	Type	Justification	Decimal Placement
1-4	Sequence Number	4	X	F	-
5-10	Prior Node	6	X	R*	-
11	Blank	1	-		
12	Action Code	1	X	F	-
13-17	WUC	5	X	F	-
18	Blank	1	-		
19-24	Next Node	6	X	R*	-
25	Blank, except header	1	A	F	-
26	Selection Mode	1	A	F	-
27-32	MSBMA or Probability(E, G)	6	N	R R	0 or (2, 5)
33	Blank	1	-		
34-38	Clock Number	5	X	F	-
39	Release	1	X	F	-
40	Type Task	1	N	F	-
41	Priority	1	N	F	-
42	Blank	1	-		
43-47	Hours	5	N	R	1
48-50	% Variance	3	N	F	0
51	Distribution Type	1	A	F	-
52	Blank	1	-		
53	Number	1	N	F	0
54-58	AFSC/AGE	5	X	L	-
59	Blank	1	-		
60	Number	1	N	F	0
61-65	AFSC/AGE	5	X	L	-
66	Blank	1	-		
67	Number	1	N	F	0
68-72	AFSC/AGE	5	X	L	-
73	Blank	1	-		
74	Number	1	N	F	0
75-79	AFSC/AGE	5	X	L	-
80	Continuation	1	A	F	-

*These fields have been coded right justified, but the LCOM program will automatically left justify them.

subsystem involved the determination as to which functions of a particular subsystem would be assimilated by the DAIS core elements, thus eliminating that function from the subsystem itself.

Analogous to this hardware partitioning was the partitioning of R&M parameter values. This process involved analysis of subsystem and LRU failure data to determine the impact of partitioning on those R&M factors. Specifically, when a function was removed from the sensor to be performed in the core, the R&M factors of that subsystem were modified accordingly to account for the removal of a portion of the subsystem. Since partitioning was done on an LRU basis, this meant subtracting those failures that pertain to the removed LRUs from the total set of failure modes for the entire subsystem and re-calculating the resulting R&M factors.

To best illustrate the mechanics of this procedure the Inertial Measurement Set (AN/ASN-90) will be used as an example.

The Inertial Measurement Set (IMS) (AN/ASN-90) is comprised of the following three LRUs:

- Inertial Measurement Unit (CN-1260/ASN-90)
- Inertial Measurement Set Control (C-7796/ASN-90)
- Adapter-Power Supply (PP-6141/ASN-90)

The inertial measurement unit (IMU) consists of a stable platform which provides a reference for the inertial components and the platform electronics assembly. The stable platform is a sealed unit with no organizational or intermediate level maintenance requirements other than removal, replacement and testing. It consists of inertial components, a four-gimbal assembly, and six removable printed circuit boards.

The IMS control (C-7796/ASN-90) controls the operation of the IMS. It provides for mode selection, manual input of magnetic variation or latitude, manual azimuth slewing through two multi-position selector switches, a three-digit and a single letter drum counter, and a counter control knob.

The adapter-power supply furnishes the necessary power to the IMS from a battery pack, an adapter, and a power supply section. The adapter contains four removable printed circuit boards and an electromechanical module. The power supply consists of six removable circuit boards and chassis-mounted components.

Both the equipment and shop MTNs are shown in Figure 9 for the current DAIS IMS and its LRUs. The R&M values for this subsystem are shown superimposed upon the baseline R&M factors which were derived from the field data. This subsystem was partitioned by transferring the functions of the IMS control to the DAIS core. The functions of this LRU in the current DAIS conceptual design configuration are to be accomplished as part of the DAIS integrated control function, interfacing with the IMS through other DAIS core elements.

While the AN/ASN-90 actually consists of the IMU, adapter-power supply, and IMS control, a separate shop maintenance network has been included for the IMS battery pack. This is a SRU which is reported individually in the field data. It was treated in the non-DAIS baseline system as if it were a separate LRU since it places demand on the maintenance system over and above the requirements established by the reporting of the adapter-power supply. However, the battery pack was eliminated from the current DAIS conceptual design configuration since there has been a time compliance technical order (TCTO) No. 720 to convert to the use of the aircraft power supply in lieu of a separate battery.

Note that while this DAIS-configured IMS was derived from the AN/ASN-90 and contains LRUs associated with that equipment it is no longer an AN/ASN-90 and is not referred to as such in Figure 9.

Referring to Figure 10 we see the failure data for the IMS control (WUC 73FC0) and the battery pack (WUC 73FF0) for the field data samples. The first factor to consider is flightline removals (RMA) for these LRUs. The two LRUs had a total of 146 flightline removals requiring shop maintenance. These 146 removals must be subtracted from the 871 flightline removals for the entire subsystem (WUC 73F00) since these LRUs will no longer be part of the avionics suite. This leaves 725 removals representing the total number flightline removals (RMA) for the current DAIS configuration.

Next, the number of maintenance actions performed on the flightline (MMA) are examined. MMAs for the IMS control and battery pack are noted to total 27 (see Figure 10). Subtracting this number from the MMA total of 567 for the IMS subsystem gives a figure of 540. This is the total number of MMAs for the IMS portion of the current DAIS configuration.

Figure 9 Maintenance Task Network for Current DAIS Inertial Measurement Set

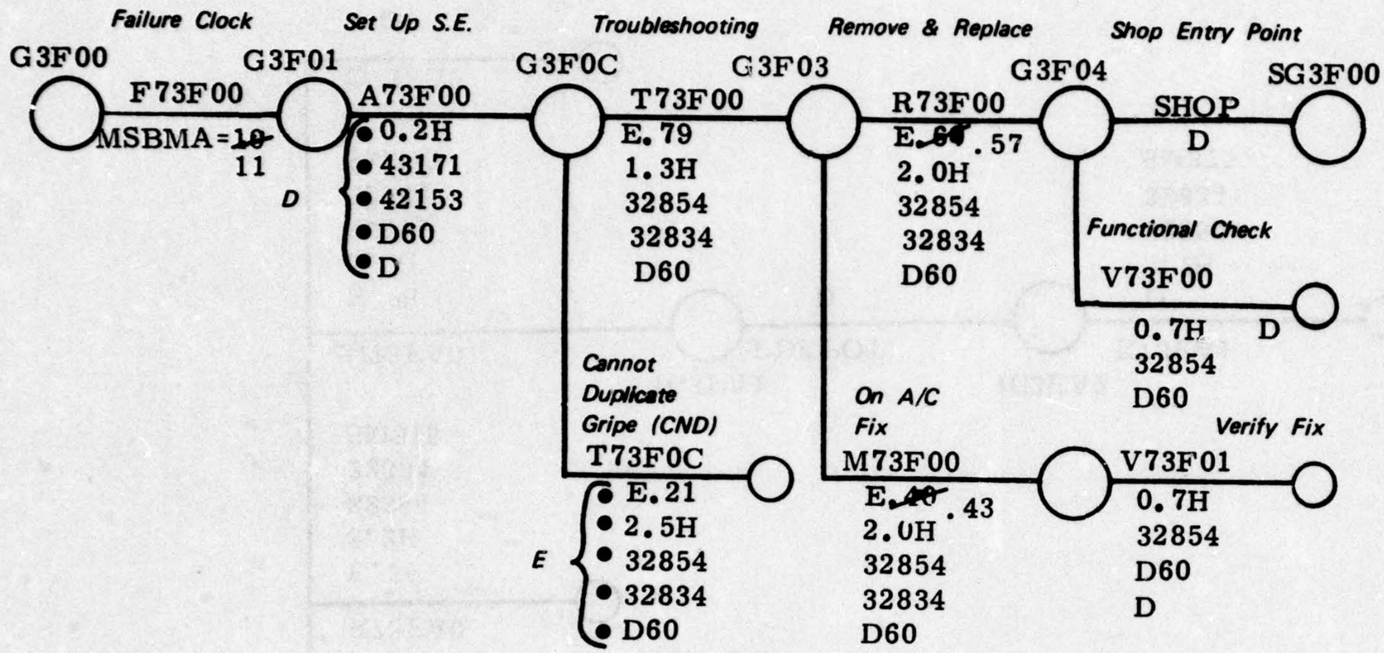


Figure 9 (continued)

INERTIAL MEASUREMENT UNIT
CN-1260/ASN-90

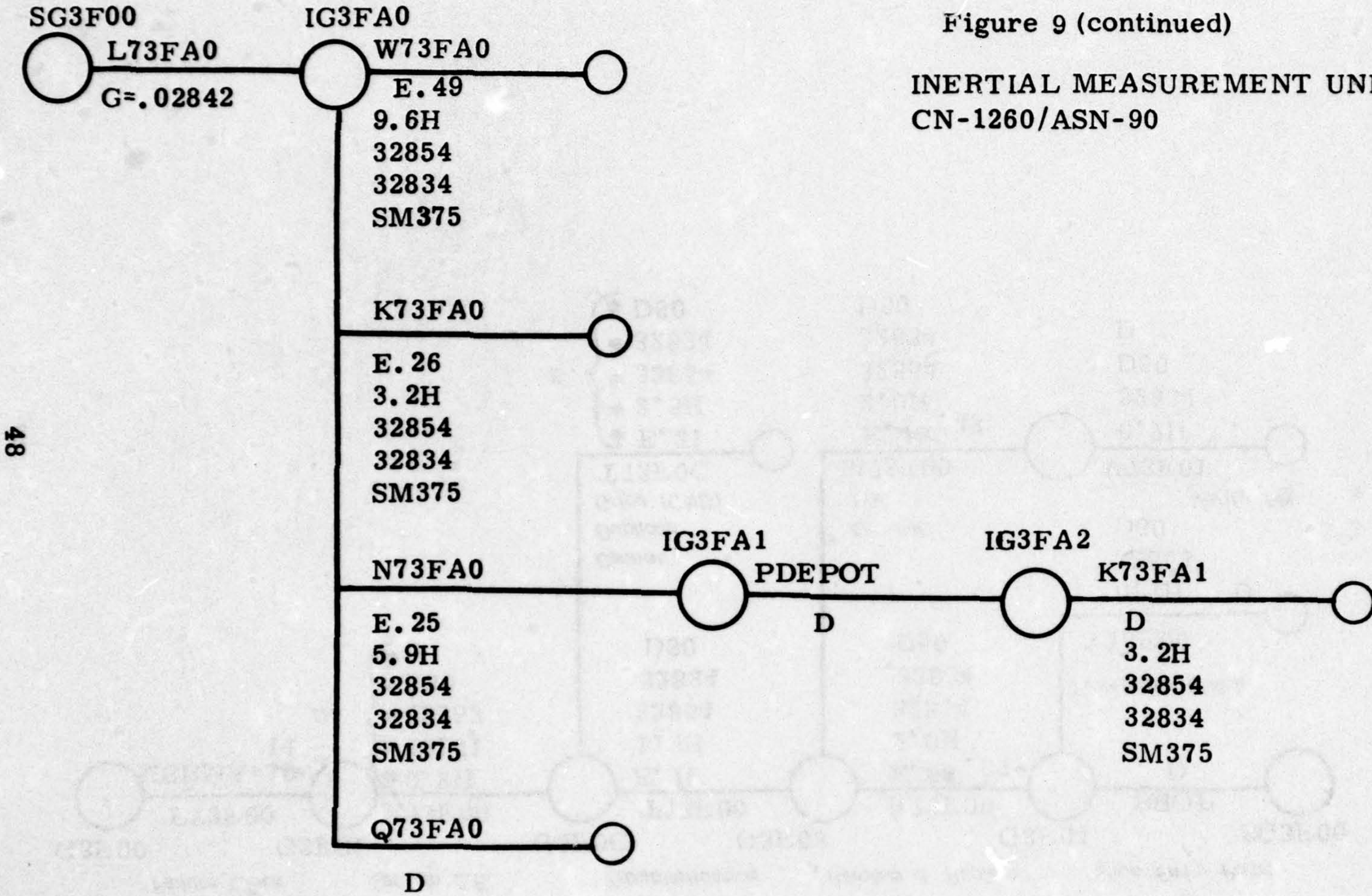


Figure 9 (continued)

ADAPTER-POWER SUPPLY
PP-6141/ASN-90

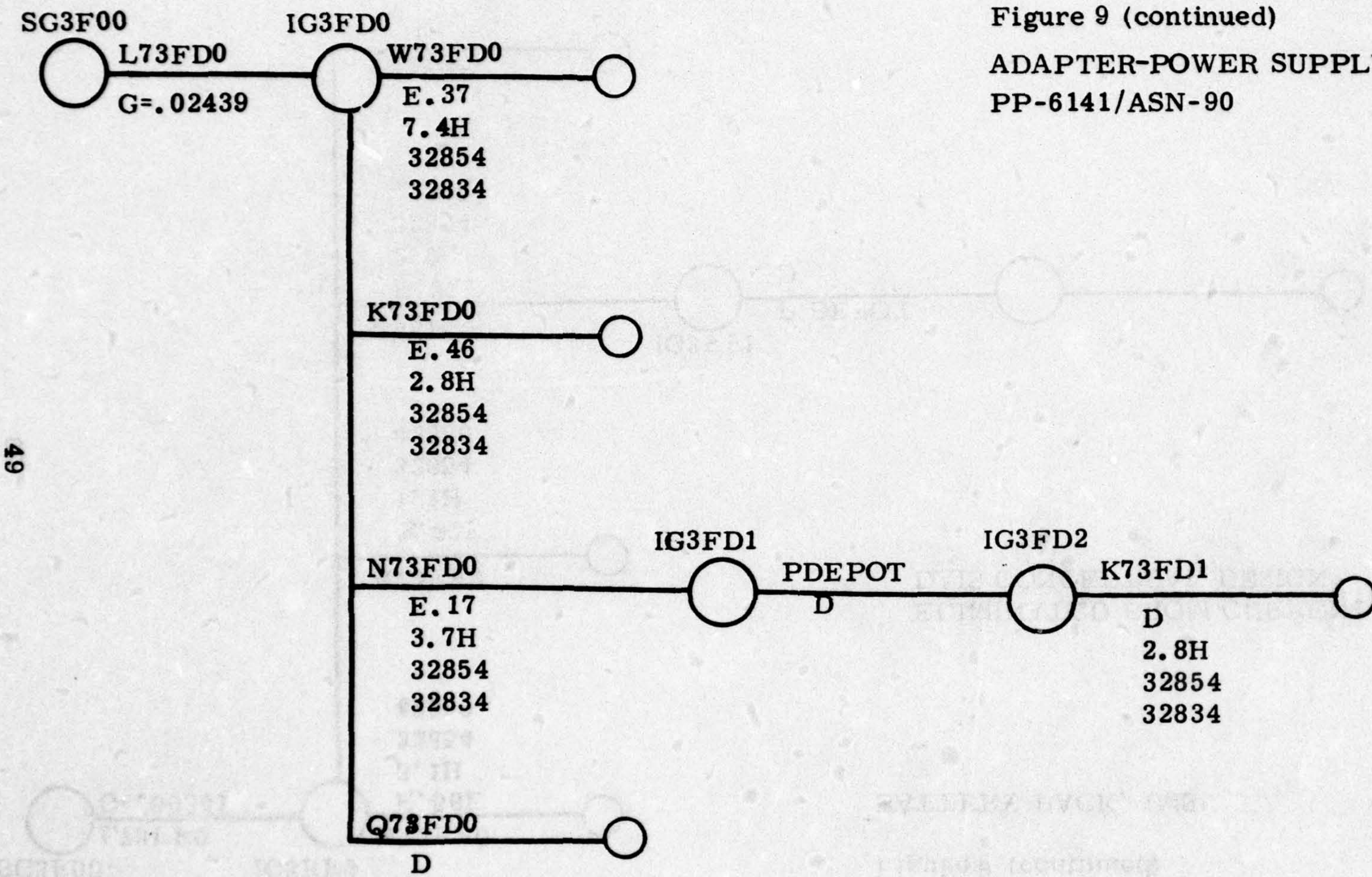


Figure 9 (continued)

BATTERY PACK, IMS

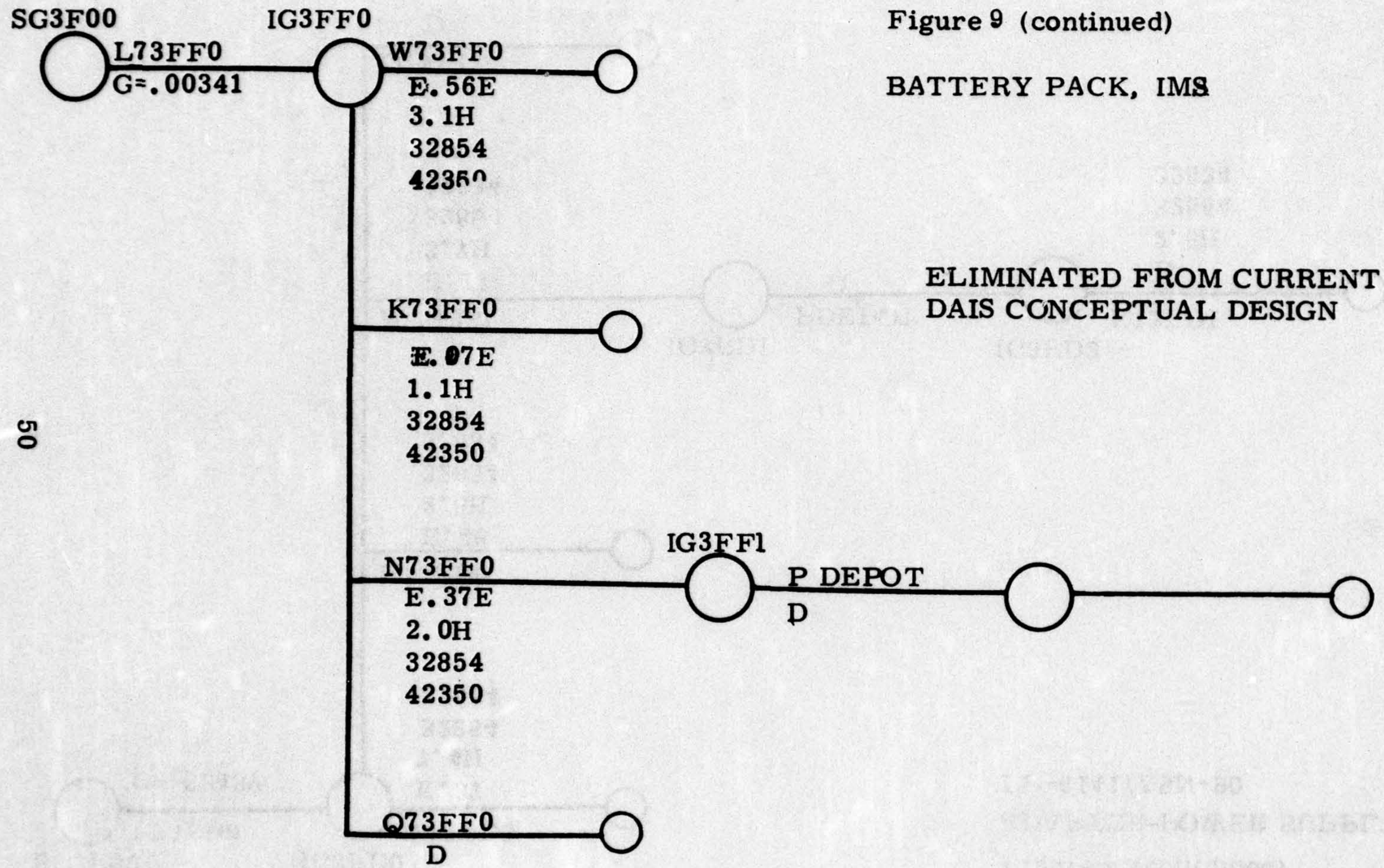
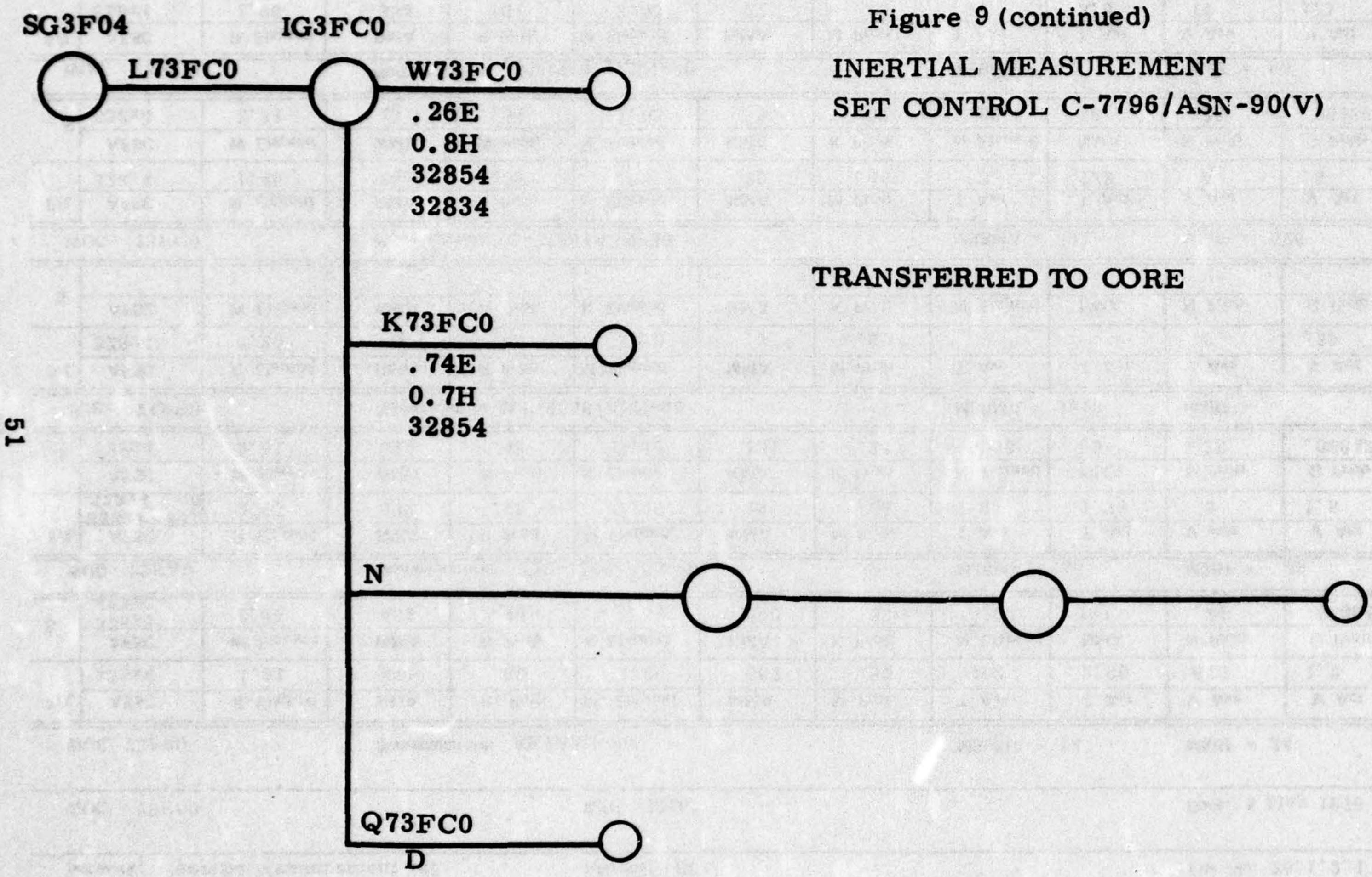


Figure 9 (continued)

INERTIAL MEASUREMENT
SET CONTROL C-7796/ASN-90(V)

TRANSFERRED TO CORE



COPY AVAILABLE TO DDC DOES NOT PERMIT FULLY LEGIBLE PRODUCTION

Figure 10 MDC RELIABILITY AND MAINTAINABILITY EXTRACTS

Network: Inertial Measurement Set AN/ASN-90 File No. 20.1.2.1

WUC: 73F00 REF: MDC Date: 5 May 1976

WUC: 73F00 Nomenclature: AN/ASN-90 MSBMA = 12 MSBF = 24

F/L	AFSC	R Elapsed	RMA	R. Prob.	M. Elapsed	MMA	M Prob	T Ave	T Act	V Ave	V Act
	328x4	1.91	871	.60	1.96	567	.39	402	2.68	670	1.2
S	AFSC	W Elapsed	WMA	W Prob	K Elapsed	KMA	K Prob	N Elapsed	NMA	N Prob	G Prob
	~~328x4~~ 423x0	8.26	454	.43	2.89	340	.32	5.02	153	.24	.06094

WUC: 73FA0 Nomenclature: CN-1260/ASN-90 MSBMA = 45 MSBF = 48

F/L	AFSC	R Elapsed	RMA	R Prob	M Elapsed	MMA	M Prob	T Ave	T Act	V Ave	V Act
	~~322x1~~/ 331 328x4 x0	2.23	372	.95	2.16	19	.06	6	1.75	5	1.8
S	AFSC	W Elapsed	WMA	W Prob	K Elapsed	KMA	K Prob	N Elapsed	NMA	N Prob	G Prob
	328x4	9.61	240	.48	3.18	131	.26	5.88	99	.25	.02842

WUC: 73FB0 Nomenclature MT-4066/ASN-90 MSBMA = 3518 MSBF =

F/L	AFSC	R Elapsed	RMA	R Prob	M Elapsed	MMA	M Prob	T Ave	T Act	V Ave	V Act
	328x4	3.20	2	.40	2.30	3	.60	-	-	9	.53
S	AFSC	W Elapsed	WMA	W Prob	K Elapsed	KMA	K Prob	N Elapsed	NMA	N Prob	G Prob

WUC: 73FC0 Nomenclature. C-7796/ASN-90 MSBMA = 391 MSBF = 926

F/L	AFSC	R Elapsed	RMA	R Prob	M Elapsed	MMA	M Prob	T Ave	T Act	V Ave	V Act
	328.4	1.45	25	.56	.68	20	.44	3	1.2	4	.6
S	AFSC	W Elapsed	WMA	W Prob	K Elapsed	KMA	K Prob	N Elapsed	NMA	N Prob	G Prob
	328x4	2.31	13	.54	1.02	5	.21	.92	6	.25	.00136

WUC. 73FD0 Nomenclature: PP-6141/ASN-90 MSBMA = 43 MSBF = 96

F/L	AFSC	R Elapsed	RMA	R Prob	M Elapsed	MMA	M Prob	T Ave	T Act	V Ave	V Act
	328x4	1.96	334	.81	2.53	77	.19	15	2.8	14	1.1
S	AFSC	W Elapsed	WMA	W Prob	K Elapsed	KMA	K Prob	N Elapsed	NMA	N Prob	G Prob
	328x4	7.41	153	.36	2.83	1.96	.46	3.74	44	.17	.02439

Figure 10 (continued)

Network: Inertial Measurement Set | **AN/ASN-90 (continued)** | **File No.** 20.1.2.1

WUC: 73F00 | **REF:** MDC | **Date:** 5 May 1976

WUC: 73FE0 **Nomenclature:** Mount Adpt/Pwr Supply **MSBMA =** 2932 **MSBF =**

F/L	AFSC	R Elapsed	RMA	R. Prob.	M. Elapsed	MMA	M Prob	T Ave	T Act	V Ave	V Act
	328x4	-	-	-	1.42	6	1.00	-	-	-	-
S	AFSC	W Elapsed	WMA	W Prob	K Elapsed	KMA	K Prob	N Elapsed	NMA	N Prob	G Prob

WUC: 73FF0 **Nomenclature:** Battery Pack **MSBMA =** 137 **MSBF =** 185

F/L	AFSC	R Elapsed	RMA	R Prob	M Elapsed	MMA	M Prob	T Ave	T Act	V Ave	V Act
	328x3 328x4	1.37	121	.95	2.42	7	.06	4	1.6	116	.7
S	AFSC	W Elapsed	WMA	W Prob	K Elapsed	KMA	K Prob	N Elapsed	NMA	N Prob	G Prob
	328x4 423x0	3.52	56	.56	1.14	7	.07	2.41	36	.36	.00580

WUC: 73FG0 **Nomenclature** Remote Compass Transmitter **MSBMA =** 2513 **MSBF =**

F/L	AFSC	R Elapsed	RMA	R Prob	M Elapsed	MMA	M Prob	T Ave	T Act	V Ave	V Act
	328x4	3.90	4	.57	3.40	3	.43	-	-	-	-
S	AFSC	W Elapsed	WMA	W Prob	K Elapsed	KMA	K Prob	N Elapsed	NMA	N Prob	G Prob

WUC: **Nomenclature:** **MSBMA =** **MSBF =**

F/L	AFSC	R Elapsed	RMA	R Prob	M Elapsed	MMA	M Prob	T Ave	T Act	V Ave	V Act
S	AFSC	W Elapsed	WMA	W Prob	K Elapsed	KMA	K Prob	N Elapsed	NMA	N Prob	G Prob

WUC. **Nomenclature:** **MSBMA =** **MSBF =**

F/L	AFSC	R Elapsed	RMA	R Prob	M Elapsed	MMA	M Prob	T Ave	T Act	V Ave	V Act
S	AFSC	W Elapsed	WMA	W Prob	K Elapsed	KMA	K Prob	N Elapsed	NMA	N Prob	G Prob

The total number of maintenance actions for the subsystem are now needed to recompute the MSBMA. Adding the total RMA and MMA figures, we get a new value of 1,265, representative of the total number of repair actions performed (725 + 540). This figure represents all removals and maintenance actions for the current DAIS network.

The value we have arrived at, 1,265 for the IMS, is the portion of the maintenance action total (MA_T) for the current DAIS network that resulted in repairs. CNDs must now be taken into consideration. A CND gripe takes place when a reported failure cannot be duplicated by subsystem operation on the flightline. This usually indicates an intermittent problem, or a temporary aberration, or that the person reporting the malfunction erred. In the case of the AN/ASN-90 (IMS) the mutually exclusive probability ("E") of a CND gripe is .18 as provided by MMS data. Since the CND gripe is associated with the entire subsystem rather than its component LRUs, and since there is no way to assign a CND contribution to a particular LRU, the CND gripe probability has been kept constant even though we have partitioned the subsystem. Therefore, we have taken the conservative approach and assumed that the mutually exclusive probability that a maintenance action is not a CND gripe is .82. Dividing 1,265 by .82 will then give us the total number of maintenance actions, MA_T, for the current DAIS network on the IMS, i.e., 1,543.

Going one step further, if the MA_T is divided into the number of sorties that the data represents, then the MSBMA for the current DAIS network is found. This could be referred to as an "adjusted" MSBMA since CND maintenance actions are included. However, since the practice of considering the CNDs has been adhered to throughout this MTA, this definition of the MSBMA is consistent with its use here. In the case of the IMS the removal of the IMS control, C-7796/ASN-90, and the battery pack changes the MSBMA from 10 to 11.

Two major changes have taken place in the R&M parameters for this function. The foregoing has described the manner in which the MSBMA, the reliability parameter, has been improved as the result of the transfer of the IMS control to core. In addition, the resources associated with the maintenance of the IMS control and battery pack (the M values) are no longer required. Other partitioned subsystems may have more functions and more LRUs transferred to the DAIS core than did this example; however, the procedure for partitioning the R&M factors remains the same. New R&M values are calculated for the subsystems and LRUs affected by transferral of LRU functions to the DAIS core element.

Core Element R&M Values

The next step in developing the current DAIS MTA data bank was to determine the R&M factors of the DAIS core elements. Since this involved new designs, the actual R&M characteristics of the subsystems in question were not available from historical data. Therefore, the use of data from similar or comparable subsystems, combined with the prediction technique, was used.

One significant problem that required solution stemmed from the fact that any information relevant to the new designs would be based on predicted or specification values whereas the data relative to the comparable systems were generally from the field. A reconciliation of these two types of data was essential to a solution to the problem. A second aspect that required addressing resulted from the fact that specification of reliability is normally in terms of mean time between failures (MTBF) while the MTNs use mean sorties between maintenance actions (MSBMA) to trigger the failure clock.

First the design specifications were consulted to determine the "required" MTBF and MTTR. Also, the functional requirements of the units were studied as to their purpose and probable design characteristics. Any comparable subsystems or LRUs in the inventory could then be identified. The R&M parameters of those subsystems identified as comparable were then noted. Their failure modes (how mal functional histories) were analyzed to predict the probability that similar failures might occur in the new design. When the characteristics of the designs were sufficiently similar so that the likelihood of similar failure modes existed the maintainability factors of the comparable subsystem were utilized directly. These maintainability factors involved the E probability of occurrence of the various parallel tasks in the networks as well as the times to perform the tasks. Where dissimilarities existed between the designs being compared, engineering judgment was used to bridge the gap. Included in the maintainability factors used directly were the number and type of specialist/technicians required to do the task. SE was specified as required.

Several computations were required in order to convert this information from the design specifications into the MSBMA required for the MTNs. Firstly, the MTBF for the individual elements or LRUs of the core elements subsystems had to be converted to subsystem MTBF. These are obtained from the following equation.

MTBF (subsystem) =

$$\frac{1}{\frac{1}{MTBF_{(LRU_1)}} + \frac{1}{MTBF_{(LRU_2)}} + \cdots \frac{1}{MTBF_{(LRU_n)}}}$$

In Table 6, the column entitled "Spec. MTBF" shows the result of this computation for the principal subsystems of the DAIS core.

The next operation was to convert these values, derived from the predictions of the subsystem LRU specifications, to values representative of field reliability experience with that type of equipment. This was accomplished through the analysis of data from the comparable subsystems and LRUs to determine the relationships between their predicted and historical MTBF. The ratios noted were used as "degradation factors" to reduce the MTBFs derived from the specifications to MTBFs predictable for the field shop. This value is shown in Table 6 as K_d. Based on the analysis of the data from the comparable subsystems a value of two was chosen as representative of avionics subsystems with the following notable exceptions:

- The heads-up display (HUD) of both the A-7D and F-15 exhibit low values of mean time between maintenance actions (MTBMA).

The MTBF value of the AVQ-7 was chosen as representative for this type of system. This resulted in a 4 to 1 K_d ratio being used for the special purpose display subsystem which consists of the heads-up display (HUD) and the vertical situation display (VSD) as LRUs.

- The MTBF of the dedicated control subsystem was degraded by an overall factor of 4. This value is based on the field experience exhibited by other control boxes. A larger K_d factor was allotted to these dedicated controls than the multifunctional controls because these LRUs retain many of the design characteristics of present control boxes; e.g., throw switches and lamps. The likelihood of damage to control boxes through usage and the cramped conditions of cockpits undoubtedly contributes to the higher maintenance rate for these units.

Table 6 MTBF K FACTORS – DAIS CORE ELEMENTS

WUC	Subsystem	Spec. MTBF	K_d	Field Shop MTBF	K_m	MFHBMA	F.H. / Sortie	MSBMA
7WA00	DAIS Electronic Display Group	6,667	2	3,334	1.77	1,887	1.7	1,110
7WB00	Special Purpose Displays	474	4	119	1.80	66		39
7WC00	Display Controls	455	2	227	1.50	151		89
7WD00	Mass Memory Unit (QPA=3)	250	2	125	1.26	99		58
7XE00	Multifunctional Controls	3,750	2	1,875	1.58	1,188		699
7XF00	Dedicated Controls	4,840	4	1,210	1.00*	1,210		712
7YA00	Processor (QPA=4)	750	10	75	2.00**	37.5		22
7ZA00	Bus Control Interface Units (QPA=4)	750	2	375	1.71	219		129
7AB00	Remote Terminal Units (QPA=10)	300	2	150	1.55	97		57

*Accounted for in the K_d value.

**This 2:1 is the utilization ratio of the computer operating time to flight hours rather than a K_m factor. The K_m is included in the K_d value.

- An overall K_d factor of 10 was used for the processors. This value was not chosen solely on the basis of projected hardware reliability. Rather it was obtained by considering the overall requirements exhibited by computers for software-related as well as hardware maintenance actions. This includes software changes, inputting and outputting data, and the need for loading and unloading tapes. Provisions were made for this in the processor specification which predicted an MTBF of 3,000 hours for the computer hardware, and an operational stability value of 300 hours, defined as the "satisfactory performance time without the necessity for readjustment or parts replacement". Using this value of 300 hours, and recognizing that four computers make up the processor subsystem gives a value of 75 hours for the MTBF to be anticipated in the field.

While K_d was used to "degrade" the specification reliability to one realistically achievable in the field, it was found necessary to introduce a second constant, K_m, to reconcile the apparent discrepancies between field reliability (actual failures) and observed values of mean time between maintenance actions (MTBMA) for the comparable subsystems. MTBMA, which is descriptive of the actual demand on the maintenance system, differs from field MTBF when maintenance actions and repairs that occur on the flightline do not get counted as failures in the shop. These include CND problems whereby a subsystem is credited with a maintenance action for which it may not be directly responsible as well as shop CNDs. Both contribute to the value of K_m. Thus, K_m is the ratio of unscheduled maintenance actions to actual failures.

The MSBMA for the MTN is computed from the field data and the specification value of $MTBF_S$ as follows:

$$\text{MSBMA} = \text{MTBMA} \left(\frac{\text{FH}}{\text{OH}}\right) \left(\frac{1}{\text{FH/S}}\right)$$

where,

MTBMA = mean time (operating hours) between maintenance actions

$\frac{\text{FH}}{\text{OH}}$ = equipment utilization ratio in flight hours per operating hour

FH/S = flight hours per sortie

$$MTBMA = \frac{OH}{MA}$$

where,

MA = no. of unscheduled maintenance actions recorded for the equipment $= \Sigma(\text{Repairs}_{F.L.} + \text{Repairs}_{shop} + \text{CNDs}_{FL} + \text{CNDs}_{shop})$

Since the field reliability is based on the number of repairs,

$$MTBF_F = \frac{OH}{\Sigma(\text{Repairs}_{F.L.} + \text{Repairs}_{shop})}$$

Thus,

$$\frac{MTBF_F}{MTBMA} = \frac{\text{Repairs}_{FL} + \text{Repairs}_{shop} + \text{CND}_{FL} + \text{CND}_{shop}}{\text{Repairs}_{FL} + \text{Repairs}_{shop}} = K_m$$

Since $MTBF_F = \frac{MTBF_s}{K_d}$

Therefore,

$$MSBMA = \frac{MTBF_s}{K_m K_d} \left(\frac{FH}{OH}\right) \left(\frac{1}{FH/S}\right)$$

A word of caution is in order at this point. Although these degradation factors were chosen based on actual field experience of avionics systems, it must be realized that when comparing the inherent reliability (R_i) designed in at the factory to the operational reliability (R_o) experienced in the field, ratios of 5 to 10 for the overall degradation factor ($K_d \times K_m$) are normally used. These factors jointly are attributable to the shipping, handling, storage, installation, operation, maintenance, and field support of the system. A contribution also results from human factors as well as the fact that the predicted MTBF is usually only attained when the system has matured and received a considerable number of engineering improvements. The values used in this analysis are predicated on steady-state system operation, one for which the reliability growth has already taken place and the "learning curve" of the field users has leveled off. Thus, a mature system has been assumed and the specified MTBF has been accepted as guaranteed by the contractor. Any improvement in the basic reliability numbers specified will have to come from reducing the K_d factor which is already extremely low. On the other hand, should experience with these subsystems show that the design MTBF cannot be met, the R figures should be adjusted downward accordingly.

For the utilization ratio a value of unity was chosen for all subsystems except the processors where a ratio of 2 was used. The rationale for this is that the processor will be operating on the ground whenever testing itself and various subsystems, or when power is applied to any of the avionics subsystems. The other subsystems, on the other hand, will have power applied only when necessary in flight or when they are being fault tested on the ground.

Reference was made to aircraft with a CAS mission capability such as the A-7D and A-7E to determine typical sortie lengths (flight hours per sortie). It was determined that a typical CAS mission involves, on the average, 1.7 flying hours. It is this value used for FH/S.

Summary

Core element reliability values in MSBMA were obtained from specified reliability (MTBF) values by solving the following equation:

$$\text{MSBMA} = \text{MTBF} \; \frac{1}{K_m K_d} \; \frac{\text{FH}}{\text{OH}} \times \frac{1}{\text{FH/S}}$$

The degradation factors, K_d and K_m, were derived through analysis of field reliability and shop maintenance data for comparable subsystems. The term $\frac{\text{FH}}{\text{S}}$ was derived through observation of operational data on A-7D and A-7E aircraft.

SUPPORT EQUIPMENT

In the case of the SE for the non-DAIS subsystems, the principal sources of information for identifying the requirements were the TOs for those subsystems. The TOs identified both the special and the general purpose test equipment needed for the maintenance of those subsystems. The listing of general purpose test equipment (GPTE) proved to be considerable. It was realized that the LCC model would require a means of determining costs of these high maintenance cost elements in terms of maintenance usage rather than simply an initial outfitting cost. Therefore, a means of lumping the overall SE requirements for each subsystem was needed to avoid the unwieldiness of listing all GPTE. The solution was to identify test stations that include the necessary test equipment to perform the

entire shop checkout, fault isolation, and calibration tests of the LRUs. Thus, it was decided to use existing test stations whenever possible to ensure that maintenance data were available. For this reason, the F-111 test stations were chosen as the representative test stations for the non-DAIS subsystems.

A comparison of the SE requirements of the selected non-DAIS CAS mission avionics conceptual design configuration to that of the current DAIS indicates that fewer equipments are required to support the current DAIS configuration. This is a direct result of the consolidation of functions into the DAIS core elements. Two test stations are sufficient to provide the testing for these core subsystems.

Consideration of modern SE concepts which utilize integrated test stations to support diverse functional groups of avionics will lead to even greater commonality of SE. These concepts are presently being implemented for the F-15 fighter aircraft. Similar concepts have already been implemented in the F-111 SE. These will be considered in the Mid-1980s DAIS MTA. A listing of the SE necessary to test the non-DAIS and current DAIS configurations is shown in Table 7. The SE is tabulated by code name against the WUC and function of the avionics subsystem being tested.

Summary

This section has described how the current DAIS MTA was performed. The manner by which partitioning sensors leads to new MTN task parameter values is described. An example is given of this process for the DAIS IMS, based on paritioning the AN/ASN-90. Similarly, a technique is described to estimate core element R&M values based on data available from comparable equipments. Finally, the SE requirements for the current DAIS are described.

This phase of the MTA is followed by an analysis of the results in the next section.

Table 7
SUBSYSTEM SUPPORT EQUIPMENT REQUIREMENTS

Subsystem		Support Equipment Codes	
WUC	**Function**	**Non-Dais**	**Current DAIS**
Flight Line	All Subsystems	D60	D60
51A00	Flight Instruments	SM565	SM565
61C00	HF Radio	GM378 SM331	GM378 SM331
62A00	VHF FM Communications	FMTS	FMTS
63510	Data Link	SM446* SM511	SM511
63A00	UHF Radio Set	RM40	RM40
63B00	Auto Direction Finding Group	RM40	RM40
64A00	Intercom Set	AICTS	AICTS
65A00	Transponder Set	PM98A PM137 PM239 PM245	PM98A PM137 PM239 PM245
71B00	TACAN Set	PM231 RM22 RM31* RM101	PM231 RM22 RM101
71C00	Radio Receiving System	RM134 SM349	RM134 SM349
72A00	Radar Altimeter	PM347 PM348	PM347 PM348
73A00	Forward Looking Radar	PM331 PM334 PM335 PM336	PM331 PM334 PM335 PM336
73B00	Tactical Computer	SM395* SM403*	
73C00	Air Data Computer	JM32 NCART	JM32 NCART
73E00	Heads-Up Display	DRYER* HUD TS*	
73F00	Inertial Measurement Set	SM375	SM375
73G00	Map Display	SM445*	

Table 7 (continued)

WUC	Subsystem Function	Support Equipment Codes Non-Dais	Current DAIS
75EA0	Missile Launcher	RM136*	
76E00	Passive ECM	PM381	PM381
76F00	Homing & Warning ECM	ADIT* ATS*	
76G00	Warning ECM	612A* WRTS*	
76X00	ECM System	LM126*	
77A00	Camera	LS83A	LS83A
7WA00	Electronic Display Group		DTS
7WB00	Special Purpose Displays		DTS
7WC00	Display Controls		DTS
7WD00	Mass Memory Unit		DTS
7XE00	Multifunction Controls		DTS
7XF00	Dedicated Controls		DTS
7YA00	Processor		CMPTS
7ZA00	Bus Control Interface Unit		CMPTS
7ZB00	Remote Terminal Unit		DTS

*The function tested by this test set having been transferred to the DAIS Core Element in the Current DAIS Configuration is tested by either the Display Indicator and Controls Test Station (DTS) or the Computer Test Station (CMPTS) which are used to test the entire integrated Controls/Displays or the Processor, respectively.

V. EVALUATION OF CURRENT DAIS R&M CHARACTERISTICS

APPROACH

Because the available R&M data and the information contained in the maintenance task networks (MTN) and the current maintenance task analysis data bank are broken down into values associated with individual maintenance tasks, a method was developed to collectively interpret these data elements. This method involved the computation of certain operational parameters called figures of merit (FOM) which are descriptive of the reliability and maintainability of the entire subsystem. As such they permit a higher degree of visibility into the impact that the R&M characteristics have on operational availability and on operations and maintenance (O&M) costs. The FOM used are: aircraft subsystem availability, maintenance man-hours/1000 flight hours, and maintenance index. These are easily calculated through the use of the MTNs and the data included therein.

AIRCRAFT SUBSYSTEM AVAILABILITY

As an indicator of operational availability, aircraft subsystem availability provides visibility into the impact that both the reliability and maintainability have on flight operations. If it is assumed that spare subsystems or LRUs are immediately available as replacements on the flightline, then the aircraft subsystem availability due to equipment maintenance can be thought of as follows:

$$\text{Aircraft subsystem availability} = A = \frac{MFHBMA}{MFHBMA + MTTR_F}$$

where

MFHBMA = mean flight hours between maintenance actions

and

$MTTR_F$ = mean time to repair at the flightline

When this FOM is calculated, the resulting value represents the fraction of total time that the aircraft is available for flight as a result of maintenance on that subsystem.

The calculation of this FOM may be understood by referring to Figure 11 representing a generalized MTN. For clarity, the network diagram originally shown in Figure 5 is reproduced at the top of the page indicating the operations performed during this equipment maintenance. The lower portion of this diagram shows the task flow indicated symbolically. The symbols used to compute the FOM are shown in their proper places on the network diagram. The equations that convert these data into terms used in the FOM are shown at the very bottom of the chart. Table 8 contains a list of and definition of each of these network terms.

The computation of aircraft subsystem availability involves the calculation of MFHBMA and $MTTR_F$. MFHBMA is related to the failure parameter, F, the mean sorties between maintenance actions (MSBMA). MFHBMA is calculated using the following relationship:

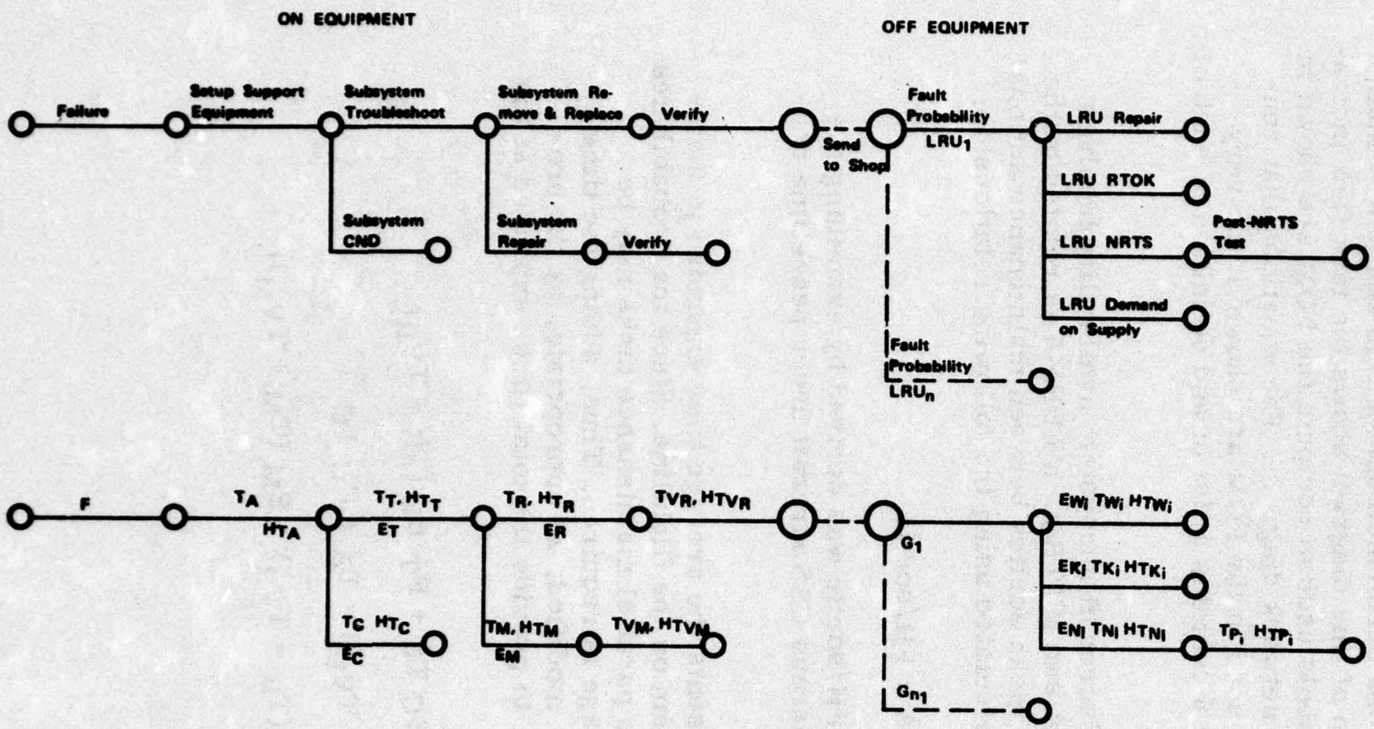
$$MFHBMA = MSBMA \times FH/sortie$$

A value of 1.7 for FH/sortie was derived by examining the flying data records of numerous CAS aircraft under peacetime conditions.

The $MTTR_F$ represents the average time expended in maintenance of a given subsystem on the flightline. Since the probabilities associated with each of the parallel maintenance tasks may be different, a weighted average is required. Thus, adding the time associated with each task, modified, as appropriate, by the probability of its occurrence, to provide the total times expended at the flightline yields:

$$\begin{aligned} MTTR_F &= T_A + E_T T_T + E_C T_C + E_T E_R (T_R + T_{V_R}) \\ &\quad + E_T E_M (T_M + T_{V_M}) = T_A + E_C T_C \\ &\quad + E_T [T_T + E_R (T_R + T_{V_R}) + E_M (T_M + T_{V_M})] \end{aligned}$$

Figure 11 USE OF MAINTENANCE TASK NETWORK IN COMPUTING FIGURES OF MERIT



Mean time to repair at the flightline = $MTTR_F = T_A + E_C T_C + E_T \left[T_T + E_R \left(T_R + TV_R\right) + E_M \left(T_M + TV_M\right)\right]$

Mean time to repair in the shop = $MTTR_S = \sum_{i=1}^{n} G_i \left[EW_i\ TW_i + EK_i\ TK_i + EN_i \left(TN_i + TP_i\right)\right]$ [MSBMA]

$MTTR_{TOTAL} = MTTR_F + MTTR_S$

Maintenance Manhours at the flightline = $MMH_F = T_A HT_A + E_C T_C HT_C + E_T \left[T_T HT_T + E_R \left(T_R HT_R + TV_R HTV_R\right) + E_M \left(T_M HT_M + TV_M HTV_M\right)\right]$

Maintenance Manhours in the shop = $MMH_S = \sum_{i=1}^{n} G_i \left[EW_i\ TW_i\ HTW_i + EK_i\ TK_i\ HT_{K_i} + EN_i \left(TN_i\ HT_{N_i} + TP_i\ HT_{P_i}\right)\right]$ [MSBMA]

Total MMH = $MMH_T = MMH_F + MMH_S$

Table 8 TERMS USED IN COMPUTING FIGURES OF MERIT

Symbol	Description
E_C	Probability that a given malfunction will result in a CND
E_{K_i}	The probability that the malfunction isolated to the i^{th} LRU will result in a RTOK
E_M	Probability that a given troubleshoot operation will result in an on aircraft repair
E_{N_i}	The probability that the malfunction isolated to the i^{th} LRU will result in a NRTS
E_R	Probability that a given troubleshoot operation will result in a removal of one or more LRUs of the subsystem
E_T	Probability that a given malfunction will result in a troubleshoot operation
E_{W_i}	The probability that the malfunction isolated to the i^{th} LRU will result in a repair operation
F	Subsystem failure cycle in mean sorties between maintenance actions (MSBMA)
G_i	Per-sortie probability that the i^{th} LRU of the subsystem will require shop maintenance
H_{T_A}	Number of human resources (maintenance technicians) required to set up support equipment
H_{T_C}	Number of human resources required to determine that a CND condition exists
$H_{T_{K_i}}$	Number of human resources required to determine that a shop CND condition exists with respect to the i^{th} LRU of a given subsystem
H_{T_M}	Number of human resources required to repair the subsystem on the aircraft
$H_{T_{N_i}}$	Number of human resources required to determine that a NRTS action exists with respect to the i^{th} LRU of a given subsystem
$H_{T_{P_i}}$	Number of human resources required to shop test a unit returning from depot
H_{T_R}	Number of human resources required to remove and replace a subsystem or portions thereof from the aircraft on the flightline

Table 8 (continued)

Symbol	Description
H_{T_T}	Number of human resources required for subsystem troubleshooting
$H_{T_{V_M}}$	Number of human resources required to verify subsystem operation following an on equipment repair
$H_{T_{V_R}}$	Number of human resources required to verify subsystem operation following a remove and replace operation
$H_{T_{W_i}}$	Number of human resources required to perform bench check and repair of the i^{th} LRU of a given subsystem
T_A	Average time required to set up support equipment
T_C	Average time required to determine that a CND condition exists
T_{K_i}	Average time required to determine that a shop CND condition exists with respect to the i^{th} LRU
T_M	Average time required to repair the subsystem on the aircraft
T_{N_i}	Average time required to determine that a not repairable this station (NRTS) or a condemnation condition exists with respect to the i^{th} LRU
T_{P_i}	Test time associated with shop test of a unit returning from depot
T_R	Average time required to remove and replace one or more of the LRUs of the subsystem from the aircraft
T_T	Average time required to troubleshoot the subsystem
T_{V_M}	Average time required to verify subsystem operation following an on equipment repair
T_{V_R}	Average time required to verify subsystem operation following a removal and replacement
T_{W_i}	Average time required to repair the i^{th} LRU in the shop

MAINTENANCE MANHOURS (MMH) PER 1000 FLIGHT HOURS (FH)

The parameter MMH per 1000 flight hours is computed from the network data as follows:

$$\text{MMH per 1000 FH} = 1000 \times \frac{\text{MMH/maintenance action}}{\text{mean flight hours/maintenance action}}$$

$$= 1000 \times \frac{MMH_T}{MFHBMA}$$

As was shown in the computation of $MTTR_F$,

$$MFHBMA = 1.7\ MSBMA$$

The MMH_T is obtained by inserting the number of people required per maintenance task into the equations defining $MTTR_F$ and $MTTR_S$ and adding the resulting values. Thus, the flightline portion of MMH_T is computed as follows using the equation derived in the previous paragraph for $MTTR_F$:

$$MMH_F = T_A H_{T_A} + E_C T_C H_{T_C} + E_T [T_T H_{T_T} + E_R$$

$$(T_R H_{TR} + T_{V_R} H_{T_{V_R}}) + E_M (T_M H_{T_M} + T_{V_M} H_{T_{V_M}})]$$

The maintenance manhours in the shop may be calculated in a similar way by first deriving an expression for $MTTR_S$, the mean time to repair in the shop. Once again, because of the probabilities associated with the performance of individual types of tasks, the $MTTR_S$ is a weighted average of the maintenance times associated with the possible maintenance activities in the shop. The LRU malfunction rates (G_i) which drive the demand on shop resources are given as probabilities of failure per sortie. In order to add the resources required at the shop level to those required at the flightline, it is necessary to relate the frequency of shop maintenance actions to that at the flightline. The LRU failure per sortie at the shop can be converted to LRU failure per flightline maintenance action by multiplying the G probabilities by MSBMA. Thus,

$$MTTR_S = MSBMA \sum_{i=1}^{n} G_i [E_{W_i} T_{W_i} + E_{K_i} T_{K_i} + E_{N_i} (T_{N_i} + T_{P_i})]$$

By analogy with the calculation of MMH at the flightline we have for shop-expended maintenance manhours:

$$MMH_S = MSBMA \sum_{i=1}^{n} G_i \left[E_{W_i} T_{W_i} H_{T_{W_i}} + E_{K_i} T_{K_i} H_{T_{K_i}} + E_{N_i} \left(T_{N_i} H_{T_{N_i}} + T_{P_i} H_{T_{P_i}} \right) \right]$$

MAINTENANCE INDEX (MI)

Additional visibility into the O&M cost drivers is sometimes afforded through use of another FOM: subsystem maintainability index (MI). As has already been noted, scheduled or preventive maintenance for avionics equipment consumes a negligible portion of the total maintenance resources. Limiting ourselves, therefore, to the MI for unscheduled maintenance, we have:

$$MI = \frac{MTTR_{Total}}{MFHBMA} = \frac{MTTR_F + MTTR_S}{MFHBMA}$$

This relationship provides a dimensionless numerical value which represents the ratio of subsystem maintainability (MTTR) to subsystem reliability (MFHBMA). Computation of the terms of this FOM has already been discussed above.

RESULTS AND CONCLUSIONS

Computations of aircraft subsystem availability (A), MMH/1000FH, and MI were carried out for the 29 subsystems comprising the current DAIS conceptual design configuration. The results are shown in Table 9 for aircraft subsystem availability (A), Table 10 for MMH/1000FH, and Table 11 for MI. Several significant observations may be made from this data.

1. The aircraft subsystem availability ranking, Table 7, shows the IMS and forward looking radar (FLR) as having availability values of 83% and 87%, respectively. The overall weapon system availability resulting from maintenance activities associated with these two subsystems is 72%. Stated in other terms, these two subsystems alone reduce the availability of the aircraft by 28% due to their flightline maintenance requirements. Clearly, these are "high burner" items in terms of restrictions on aircraft availability and the resultant impact on operational readiness.

Table 9 AIRCRAFT SUBSYSTEM AVAILABILITY RANKING

$$A = \frac{MFHBMA}{MFHBMA + MTTR_F}$$

WUC	EQUIPMENT NAME	MFHBMA	$MTTR_F$	A
73F00	Inertial Measurement Set	18.7	3.98	8278
73A00	Forward Looking Radar	35.7	5.32	.8703
7YA00	Processor	37.4	2.02	.9488
51A00	Flight Instruments	54.4	2.86	.9500
71B00	TACAN Set	40.8	2.10	.9510
72A00	Altimeter Set	35.7	1.60	.9571
7WB00	Special Purpose Displays	47.6	2.06	.9585
73C00	Air Data Computer	74.8	3.12	.9599
63A00	UHF Radio	52.7	2.08	.9622
61A00	HF Radio	47.6	1.72	.9650
62A00	VHF-FM Comm.	69.7	2.20	.9694
71A00	HSI & ADI	122.4	3.47	.9721
63510	Data Link	119.0	2.56	.9789
76E00	RHAW	102	2.03	.9805
72B00	Radar Beacon Set	76.5	1.33	.9829
7ZB00	Remote Terminal Unit	149.6	2.56	.9832
71C00	Radio Receiving System	107.1	1.82	.9833
65A00	Transponder Set	115.6	1.94	.9835
64A00	Intercom	146.2	2.31	.9840
7WD00	Mass Memory Unit	154.7	2.47	.9843
69A00	Speech Security System	119.0	1.49	.9876
7WC00	Display Controls	227.8	1.91	.9917
63B00	Automatic Direction Finder	278.8	2.29	.9919
7ZA00	Bus Control Interface Unit	374.0	2.73	.9928
77A00	Strike Camera	1150.9	6.21	.9946
51B00	Navigation Instruments	680.0	3.50	.9948
7XE00	Multifunction Controls	1241.0	2.01	.9984
7XF00	Dedicated Controls	1210.4	1.97	.9984
7WA00	Electronic Display Group	3332.0	2.07	.9994

Table 10 MAINTENANCE MANHOUR RANKING

$$MMH/1000FH = \frac{MMH_T \times 1000}{MFHBMA}$$

WUC	EQUIPMENT NAME	MMH_F	MMH_S	MMH/1000FH
73F00	Inertial Measurement Set	7.21	7.64	794.12
73A00	Forward Looking Radar	9.85	6.64	461.90
61A00	HF Radio	3.43	10.49	292.44
7WB00	Special Purpose Displays	3.52	10.28	289.92
71B00	TACAN Set	3.79	5.92	237.99
72A00	Altimeter Set	3.19	3.85	197.20
63A00	UHF Radio	3.46	6.71	192.98
7YA00	Processor	4.03	2.07	163.10
73C00	Air Data Computer	6.24	4.50	142.44
62A00	VHF-FM Comm.	4.40	4.50	127.69
51A00	Flight Instruments	5.72	.45	113.24
7ZB00	Remote Terminal Unit	5.11	7.58	84.83
7WD00	Mass Memory Unit	4.67	4.75	60.89
76E00	RHAW	4.07	1.96	59.12
71A00	HSI & ADI	6.47	.66	58.25
65A00	Transponder Set	3.23	2.78	51.99
63510	Data Link	3.97	1.88	49.16
64A00	Intercom	4.62	1.99	45.21
71C00	Radio Receiving System	3.37	1.24	43.04
7WC00	Display Controls	3.64	9.73	42.71
7ZA00	Bus Control Interface Unit	5.44	9.08	38.82
63B00	Automatic Direction Finder	4.58	3.12	27.62
69A00	Speech Security System	2.79	.39	26.72
72B00	Radar Beacon Set	2.65	1.01	15.95
51B00	Navigation Instruments	7.00	2.37	13.78
77A00	Strike Camera	12.48	2.57	13.02
7XE00	Multifunction Controls	4.02	8.57	10.15
7XF00	Dedicated Controls	3.94	1.94	4.86
7WA00	Electronic Display Controls	3.96	6.64	3.18

Table 11 MAINTENANCE INDEX RANKING

$$MI = \frac{MTTR_F + MTTR_S}{MFHBMA}$$

WUC	EQUIPMENT NAME	$\frac{MTTR_{Total}}{MFHBMA}$
73F00	INERTIAL MEASUREMENT SET	.3891
73A00	FORWARD LOOKING RADAR	.2429
7WB00	SPECIAL PURPOSE DISPLAYS	.1513
61A00	HF RADIO	.1462
71B00	TACAN	.1341
63A00	UHF RADIO	.1032
72A00	ALTIMETER SET	.0986
73C00	AIR DATA COMPUTER	.0853
7YA00	PROCESSOR	.0816
62A00	VHF-FM COMM.	.0638
51A00	FLIGHT INST.	.0594
7WC00	DISPLAY CONTROLS	.0450
7ZB00	REMOTE TERMINAL UNIT	.0424
71A00	HSI & ADI	.0335
7WD00	MASS MEMORY UNIT	.0317
76E00	RHAW	.0295
63510	DATA LINK	.0294
65A00	TRANSPONDER	.0288
72B00	RADAR BEACON SET	.0241
71C00	RADIO RECEIVING SYSTEM	.0228
64A00	INTERCOM	.0220
7ZA00	BCIU	.0194
69A00	SPEECH SECURITY SYSTEM	.0154
51B00	NAV INST.	.0086
77A00	CAMERA	.0066
7XE00	MULTIFUNCTION CONTROLS	.0051
7XF00	DEDICATED CONTROLS	.0024
7WA00	ELECTRONIC DISPLAY GROUP	.0016
63B00	ADF GROUP	.0014

2. The MMH/1000FH ranking shows the priorities by which demand is placed on the resources provided by the maintenance system. While this chart is based on human resource expenditure, inferences can be drawn regarding SE utilization as well since fixed ratios exist between MTTR and the fraction of the repair time that test equipment is used for the respective subsystems.

The following percentages were calculated from the data of Table 8. They indicate the breakout of human resource expenditures by subsystem.

Subsystem	% Human Resources Consumed
Inertial Measurement Set	22
Forward Looking Radar	13
HF Radio	8
Special Purpose Displays	8

The first two subsystems consume 35% of the MMH required for DAIS avionics maintenance. All four subsystems shown above consume 51%. These are clearly "high burner" items wherein reliability and maintainability improvements will provide the maximum O&M cost reductions.

3. Additional visibility is provided by the MI ranking of Table 9. It has already been established from the discussion of Table 8 (MMH/1000FH) that IMS and FLR consume a significant share of the maintenance resources required for the entire current DAIS conceptual design configuration. The MMH/1000FH data gives no clue as to the cause. Perhaps it is due to a large average repair time (MTTR). On the other hand, it could be due to a high failure rate. Even a small value of MTTR might show up as a high driver in terms of MMH/1000FH if frequent repairs of a given subsystem tie up a lot of manpower.

The ranking shown in Table 9 shows the IMS and FLR in the top positions for the MI. Since MI is directly proportional to MTTR while inversely proportional to MFHBMA, this condition is possible only if both reliability and maintainability contribute to the poor MI of these subsystems. Only the engineering analysis of the design characteristics bearing on both the R&M of these subsystems will lead to any significant reduction in the consumption of maintenance resources on the part of these subsystems.

The rankings provide the basis for tradeoff analyses in which similar subsystems can be compared to those listed to determine the impact of their substitution. Using the MMH/1000FH ranking, conclusions can be drawn regarding maintenance manpower requirements. Utilizing suitable labor rate conversion factors plus SE utilization factors leads to direct comparisons of O&M costs. Similarly, comparisons of the impact of such substitutions on operational readiness may be inferred using the aircraft subsystem availability ranking.

Other tradeoffs can be made. These will depend upon the design of other FOMs. For example, rankings on MSBMA will show which subsystems are the high drivers as a result of reliability alone. Rankings on MTTR will show the sensitivity to maintainability parameter changes. These will provide the information needed to impact the design in order to most effectively reduce O&M costs. Most important, the data contained in the current DAIS maintenance task analysis data bank is amenable to data manipulations which not only indicate potential problem areas but also afford insights into possible approaches to problem resolution.

REFERENCES

1. Frank A. Maher and Michael L. York, Simulation Maintenance Manning for New Weapon Systems: Maintenance Manpower Management During Weapon System Development. AFHRL-TR-74-97(I), AD-A011986. Wright-Patterson AFB, OH, Advanced Systems Division, Air Force Human Resources Laboratory, December 1974.

2. Donald C. Tetmeyer and William D. Moody, Simulating Maintenance Manning for New Weapon Systems: Building and Operating a Simulation Model. AFHRL-TR-74-97(II), AD-A011987. Wright-Patterson AFB, OH, Advanced Systems Division, Air Force Human Resources Laboratory, December 1974.

3. Donald C. Tetmeyer and Sharon R. Nichols, Simulating Maintenance for New Weapon Systems: Maintenance Data Analysis Program. AFHRL-TR-74-97(III), AD-A025342. Wright-Patterson AFB, OH, Advanced Systems Division, Air Force Human Resources Laboratory, December 1974.

4. Verlesta B. Hicks and Donald C. Tetmeyer, Simulating Maintenance for New Weapon Systems: Data Base Management Programs. AFHRL-TR-74-97(IV), AD-A011989. Wright-Patterson AFB, OH, Advanced Systems Division, Air Force Human Resources Laboratory, December 1974.

5. Donald C. Tetmeyer and Sharon R. Nichols, Simulating Maintenance Manning for New Weapon Systems: Manpower Programs. AFHRL-TR-74-97(V), AD-A011990. Wright-Patterson AFB, OH, Advanced Systems Division, Air Force Human Resources Laboratory, December 1974.

6. William F. Drake, et al., Logistics Composite Model Users Reference Guide, AFLC Report; AD703328, January 1970.

7. William F. Drake III. Logistics Composite Model User Reference Guide Update. AFLC/ADDR Report 74-1, November 1974.

8. Air Force Manual 66-1, Maintenance Management; Vol I - IV, VIII; 1 May 1974.

9. A. J. Czuchry, et al., A Mid-1980s Digital Avionics Information System Conceptual Design Configuration. AFHRL-TR-76-59. Wright-Patterson AFB, OH, Advanced Systems Division, Air Force Human Resources Laboratory, May 1976.

10. Catalog of Information Reports for 3-M Aviation; Navy Fleet Material Support Office, FMSOINST 4790. 1A; 18 January 1974.

11. ASCC Cross-Servicing Manual, Airborne Electronic Systems; Volumes 11A and 11B; Air Standardization Coordination Committee, March 1974.

12. Military Standard 280, Definition of Terms for Equipment Divisions, 4 April 1956.

13. Military Standard 470, Maintainability Program Requirements (for Systems and Equipment), 21 March 1966.

14. Military Standard 471, Maintainability Demonstration, 15 February 1966.

15. Military Standard 721B, Definitions for Effectiveness Terms for Reliability, Maintainability, Human Factors, and Safety, 25 August 1966.

16. Military Standard 756A, Reliability Prediction, 15 May 1963.

17. Military Standard 781A, Reliability Tests Exponential Distribution, 10 December 1965.

18. Military Standard 785A, Reliability Program for Systems and Equipment Development and Production, 28 March 1969.

19. Military Standard 1388-1, Logistic Support Analysis, 15 October 1973.

20. Military Standard 1388-2, Logistics Support Analyses Data Element Definitions, 15 October 1973.

21. Air Training Command Pamphlet 35-6, Military Personnel, USAF Specialty and Requirements Guide, 23 October 1975.

22. AFLC Manual 66-18, Equipment Maintenance, Programming and Technical Processes, 10 July 1970.

23. Military Standardization Handbook 472, Maintainability Prediction, 24 May 1966.

24. Lawrence E. Dover, et al., A Summary and Analysis of Selected Life Cycle Costing Techniques and Models, AD-787183, Air Force Institute of Technology.

25. Logistics Support Cost Model User's Handbook, AFLC/AQA, June 1975.

GLOSSARY OF ACRONYMS

A	availability
ADI	attitude direction indicator
AFAL	Air Force Avionics Laboratory
AFHRL	Air Force Human Resources Laboratory
AFLC	Air Force Logistics Command
AFSC	Air Force specialty codes
ATC	action taken code
CAS	close air support
CITS	central integrated test system
CF	CITS improvement factor
CND	cannot duplicate
DAIS	digital avionics information system
DAIS ADP	DAIS advanced development program
DRC	Dynamics Research Corporation
E	mutually exclusive probability
ECM	electronic countermeasures
EDB	engineering data base
FH	flight hours
FOM	figure of merit
GPTE	general purpose test equipment
HF	high frequency
HSI	horizontal situation indicator
HUD	heads-up display
IMA	intermediate maintenance level (shop) activities
IMS	inertial measurement set
IMU	inertial measurement unit
JPA	job performance aids
K_d	degradation factor
K_m	ratio of unscheduled maintenance actions to actual failures requiring shop action
KMA	number of bench check OK (shop CND) maintenance actions
LCC	life cycle cost
LCOM	logistics composite model
LRU	line replaceable unit
LSC	logistics support cost
MA_T	total maintenance actions
MADAR	malfunction analysis detection and recording system
MDC	maintenance data collection
MDCS	maintenance data collection system
MFHBMA	mean flight hours between maintenance actions

MI	maintenance index
MMA	maintenance actions performed on the flight line
MMH	maintenance manhours
MMH/ATC	maintenance manhours per action taken code
MMH/FH	maintenance manhours per flight hour
MMH/MA	maintenance manhours per maintenance action
MMS	maintenance manpower system
MMMS	maintenance manpower modeling system
MSBF	mean sorties between failures
MSBMA	mean sorties between maintenance actions
MTA	maintenance task analysis
MTBF	mean time between failures
MTBMA	mean time between maintenance actions
MTN	maintenance task network
MTTR	mean time to repair
NAVAIR	Naval Air Systems Command
NMA	number of bench check and NRTS maintenance actions
NRTS	not repairable this station
OH	operating hours
O&M	operation and maintenance
QPA	quantity per aircraft
R_I	inherent reliability
R_O	operational reliability
R&M	reliability and maintainability
RMA	number of flightline remove and replace maintenance actions
RTOK	retest OK
SE	support equipment
SPO	system project office
TAT	turn around time
TCTO	time compliance technical order
TO	technical order
TOA	table of allowances
USAF	United States Air Force
VSO	vertical situation display
WMA	number of bench check and repair maintenance actions
WUC	work unit code

Appendix A

LIST OF DOCUMENTATION

The following documentation items, which include reports, specifications, and manuals (T.O.s), have been reviewed and utilized in this study.

DATA BASE OUTPUTS AND REPORTS

Item	Source	Title
1	66-1	Maintainability Reliability Summary, D056B5527 A-7D Nov 1974 - Oct 1975 F-15 Mar 1975 - Feb 1976 C-5A Mar 1975 - Feb 1976 F-111E Mar 1975 - Feb 1976
2	66-1	Detail Shop Actions for Selected Work Unit Codes D056B5504, Period Ending 31 Oct 1975 for the A-7D Aircraft
3	66-1	Detail Maintenance Actions for Selected Work Unit Codes, D056B5503, Period Ending 31 Oct 1975 for the A-7D Aircraft
4	66-1/ IROS	K051●PN1M, Weapon System Effectiveness Program and Models - Logistics Support Cost Ranking Segment A-7D Data as of June 1975 F-15 Data as of Dec 1975 F-111D Data as of Dec 1975 F-111E Data as of Dec 1975 C-5A Data as of Dec 1975
5	66-1/ IROS	K051●YN2M, System Availability Model Work Unit Code Status A-7D Data as of June 1975 F-15 Data as of Dec 1975 F-111D Data as of Dec 1975 F-111E Data as of Dec 1975 C-5A Data as of Dec 1975
6	3-M	Fleet Weapon System Reliability and Maintainability Statistical Summary Tabulation, MSO 4790.A2142-01 A-6E Aircraft July 1975 - Dec 1975 A-7E Aircraft Jan 1975 - July 1975 A-7E Aircraft July 1975 - Dec 1975 F-14A Aircraft July 1975 - Dec 1975

Data Base Outputs and Reports (continued)

Item	Source	Title
7	3-M	Navy/Aviation Component Repair Report, MSO 4790.A2245-01 A-6E Aircraft July 1975 - Dec 1975 A-7E Aircraft Jan 1975 - June 1975 A-7E Aircraft July 1975 - Dec 1975 F-14A Aircraft July 1975 - Dec 1975
8		A-7D Operations and Maintenance Modeling Assumptions Based on Information Obtained at 354TFW (Prepared in accordance with LCOM Extended Form 11) 1974; Data from Myrtle Beach, England, and Davis-Monthan Air Force Bases.
9		Table of Allowances #293, A-7D Weapon System, 1 Dec 1975; USAF
10		Table of Allowances #289, F-15 Weapon System, 15 Jan 1976; USAF
11		Model A-7D Integrated Configuration List for Aircraft Serial Numbers: AF68-8220, AF68-8225 through AF68-8231 and AF69-6188 through AF69-6244; Vought Aeronautics Div., LTV Aerospace Corp, 1 Feb 1971
12		Consolidated A-7 Work Unit Code List; Vought Aeronautics, LTV Aerospace Corp; 1 Mar 1973
13		MMS Pre-Processing Programs Output (program file I & II) for the A-7D, Jan - June 1975; Feb - July 1974

DAIS SPECIFICATIONS

Item	Title
1	DAIS Control/Display System Segment, Prime Item Development Specification; Purchase Request No. FY11757510260, Specification No. DHB-CD-1, -4, -5, -6, -7, -8, -10, -11.
2	Prime Item Development Specification for DAIS Bus Control Interface Unit; Type B1, Form 2, Part I; SA31300B, 15 March 1976.

DAIS SPECIFICATIONS (continued)

Item	Title
3	Critical Item Development Specification for the DAIS Processor; Attachment #2 to F33615-75-R-1154.
4	DAIS Control and Display Hardware Development; F33615-75-R-1300; 24 Jan 1975.
5	Standard Remote Terminal Development Program, DAIS Remote Terminal Statement of Work - Attachment #1, 7 Nov 1974, F33615-75-C-1180.

TECHNICAL ORDERS/MANUALS

5N29-8-2	Display Unit IP-1103/AVQ-20
5N29-4-2	Head-Up Display Set, AN/AVQ-7
5N1-5-2-2	Projected Map Display Set, AN/ASN-99A
12R2-2ARC123-2	Radio Set, AN/ARC-123
12R2-2ARC123-22	Receiver-Transmitter, Radio, RT-822/ARC-123
12R2-4-90-2	Radio Set, FM-622A
16-30ASW25-1	(NAVAIR) Communications Set, Digital Data (Data Link), AN/ASW-25A
12R2-2ARC51-2	Radio Sets AN/ARC-51, 51A, 51AX, 51B
12R2-2ARC109-2	Radio Set AN/ARC-109
12R1-2ARA50-2	Direction Finder Group AN/ARA-50
12R2-2AIC25-2	Intercommunications Set AN/AIC-25
12R2-2AIC18-2	Intercommunications Set AN/AIC-18 and Set Controls C-3814/ARC-89
12P4-2APX72-2	Receiver-Transmitter, Radio and Mountings RT-859/APX-72
12R2-2ARN52-12	TACAN Navigation Set AN/ARN-52
12R5-2ARN58-2	Radio Receiving Set AN/ARN-58
12P5-2APN141-2	Electronic Altimeter Set AN/APN-141
12P5-2APN154-2	Radar Beacon AN/APN-154
12P2-2APQ126-2-1	Radar Set AN/APQ-126 Vol I
12P2-2APQ126-2-2	Radar Set AN/APQ-126 Vol II
12P2-2APQ126-2-3	Radar Set AN/APQ-126 Vol III
12P2-2APQ126-2-4	Radar Set AN/APQ-126 Vol IV
12P2-2APQ126-2-5	Radar Set AN/APQ-126 Vol V
5F5-4-21-3	Air Data Computer CP-953/AJQ
5N16-3-6-2	Inertial Measurement Set AN/ASN-90
12P3-2ALR46-2	Countermeasure Receiver R-1854/ALR-46
12P3-2APR36-2	Radar Receiving Set AN/APR-36
12P3-2ALR46-2	Countermeasure Receiver R-1854/ALR-46

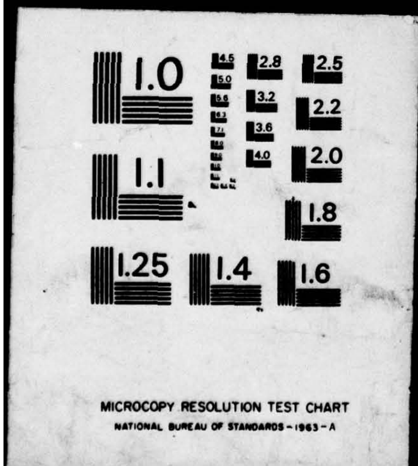
AD-A035 683 DYNAMICS RESEARCH CORP WILMINGTON MASS F/G 1/3
DIGITAL AVIONICS INFORMATION SYSTEM (DAIS): CURRENT MAINTENANCE--ETC(U)
OCT 76 H E ENGEL, J M GLASIER, R A DOWD F33615-75-C-5218
UNCLASSIFIED AFHRL-TR-76-71 NL

2 OF 2.
AD
A035683

END
DATE
FILMED
3-77

2 OF 2

035683



TECHNICAL

10A1-6-6-2
10A1-2-10-
5N5-13-13-
12P3-2ALE
12P5-2APN
12P3-2APR
11L1-2-10-
11W1-27-7-
5A1-2-43-2
1A-7D-1
1A-7D-06
10-45AA-8
1A-7D-2-8
1A-7D-2-9
1A-7D-2-10
1A-7D-2-12

1A-7D-2-13
1A-7D-2-14
1A-7D-2-18
1A-10A-06
1F-15A-06
1F-111E-06
1C-5A-06

TECHNICAL ORDERS/MANUALS (continued)

10A1-6-6-2	Still Picture Camera KB-18A, KB-18B
10A1-2-10-2	Motion Picture Camera KB-27A
5N5-13-13-2	Tactical Computer AN/ASN-91
12P3-2ALE38-2	Dispenser System AN/ALE-38
12P5-2APN190-2	Radar Navigation AN/APN-190
12P3-2APR-37-2	Radar Receiving Set AN/APR-37
11L1-2-10-1	Aircraft Guided Missile Launcher LAU-88/A
11W1-27-7-2	Gun Control DCK-203/A49E-6 for the GAU-8/A
5A1-2-43-2	Automatic Flight Control Set AN/ASW-38
1A-7D-1	A-7D Aircraft Flight Manual
1A-7D-06	Work Unit Code Manual, A-7D
10-45AA-8	(NAVAIR) Work Unit Code Manual, A-7E
1A-7D-2-8	Flight Control Systems, A-7D
1A-7D-2-9	Automatic Flight Control Systems, A-7D
1A-7D-2-10	Instrument Systems, A-7D
1A-7D-2-12	Radio Communication & Navigation Systems, A-7D
1A-7D-2-13	Armament Systems, A-7D
1A-7D-2-14	Weapon Control Systems, A-7D
1A-7D-2-18	Integrated Avionics Systems, A-7D
1A-10A-06	Work Unit Code Manual, A-10
1F-15A-06	Work Unit Code Manual, F-15
1F-111E-06	Work Unit Code Manual, F-111E
1C-5A-06	Work Unit Code Manual, C-5A

★U.S. GOVERNMENT PRINTING OFFICE:1977- 771-057/25